A STUDY OF THE PLEISTOCENE DEPOSITS AND WATER-BEARING STRATA OF THE HARDINVILLE AND SUMNER, ILLINOIS, QUADRANGLES

BY

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THESIS

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

DAVID GROSH THOMPSON

ENTITLED A STUDY OF THE PLEISTOCENE DEPOSITS AND WATER-BEARING STRATA OF THE HARDINVILLE AND SUMNER, ILLINOIS, QUADRANGLES

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN GEOLOGY

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ILLUSTRATIONS.

INTRODUCTION.

LOCATION AND AREA.

The area described in this paper lies in southeastern Illinois, and includes parts of Crawford, Jasper, Lawrence, Richland, Wabash, and Edwards counties. Topographic maps of the area have been published by the United States Geological Survey, under the titles of the Hardinville and Sumner, Illinois, quadrangles.[1] The Hardinville quadrangle lies between parallels 38°45', and 39°00', and between meridians 87°45' and 88°00'. The Sumner quadrangle adjoins the Hardinville quadrangle on the south, having the same meridional boundaries, but is included between the parallels 38°45' and 38°30'. Thus each sheet represents one-sixteenth of a square degree on the earth's surface, the maps being called fifteen minute sheets. The average width of the area is 13.5 miles and the combined length of the two quadrangles is 34.5 miles, the total area being 467.35 square miles.[2]

That part of the Hardinville quadrangle bordering the Embarass River has also been mapped on a large scale, 2,000 feet

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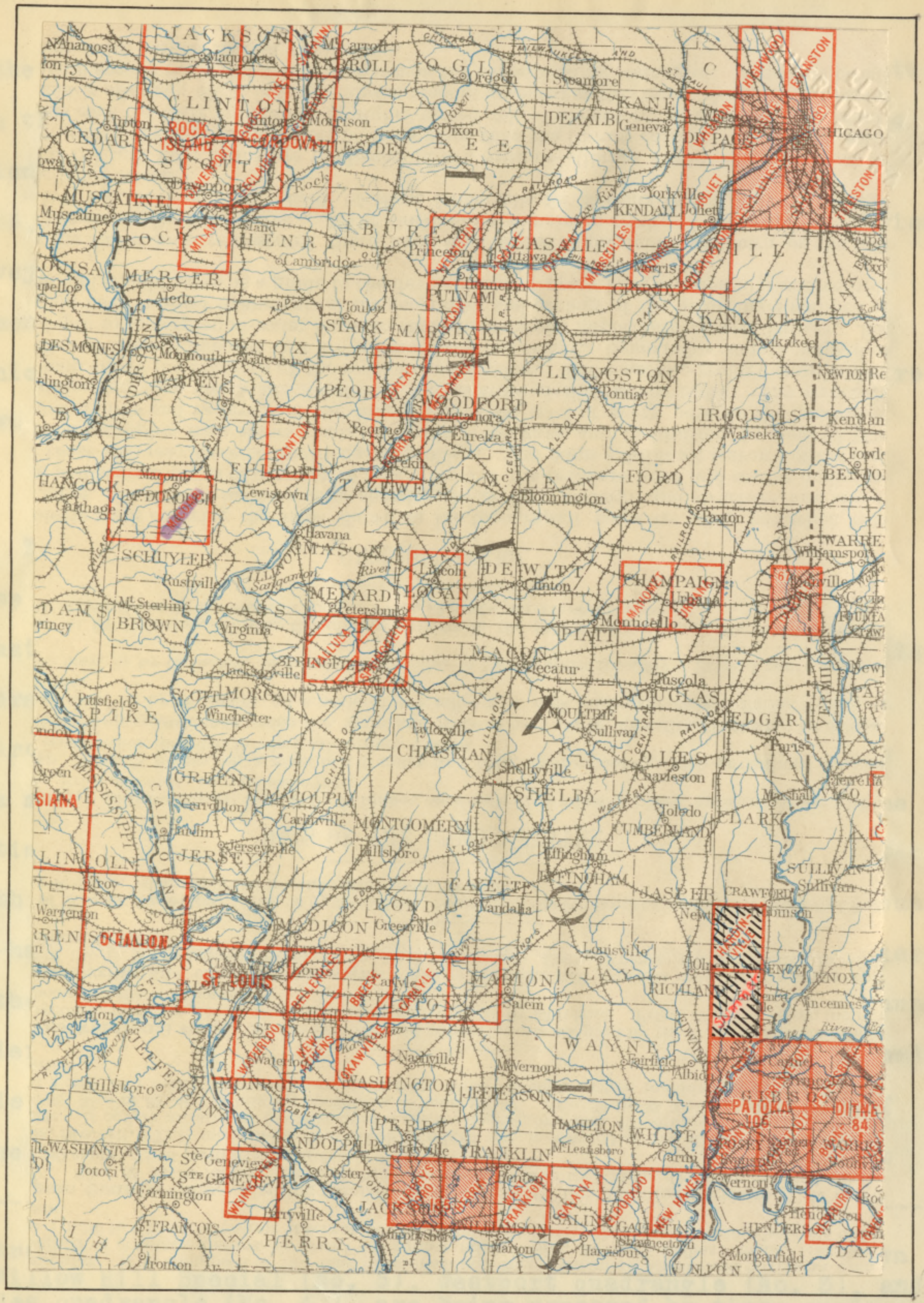
[1] The Hardinville sheet may be purchased from the Director of the United States Geological Survey, Washington, D. C., for 10 cents. The Sumner sheet is not yet ready for distribution.

[2] Gannett, S. S., Geographic tables and formulas: Bull. U. S. Geol. Survey No. 234, 1904, p. 99.

Plate I.



Index map showing location and extent of area discussed in this report obliquely lined in black.

to the inch, by the United States Geological Survey in cooperation with the Illinois Geological Survey.[1] A geologic folio of the region immediately south of the Sumner quadrangle, the Patoka folio, No. 105, has been published by the United States Geological Survey. This folio embraces the Mt. Carmel, Princeton, New Harmony, and Haubstadt fifteen minute quadrangles. The geographical relations of the Hardinville and Sumner quadrangles are shown on the index map in Plate I.

CULTURE.

This region is primarily one of agricultural pursuits. Three towns of importance in the two quadrangles are: Oblong, situated near the center of the northern side of the Hardinville quadrangle, on the Indianapolis branch of the Illinois Central Railroad, the greater part of the town lying just north of the area mapped; and Bridgeport and Sumner which are located on the Baltimore and Ohio Southwestern Railroad, two miles south of the north border of the Sumner quadrangle, the former situated about one-half mile from the east side, and the latter about six miles further west. Smaller towns in the area are Hardinville, Chauncey, Millersville, and Stoy on the Hardinville quadrangle, and Friendsville, Lancaster, and Claremont on the Sumner quadrangle. Of these smaller towns, Claremont and Stoy are the only ones that

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[1] Three sheets covering part of this area, on this scale, known as Willow Hill Special (No. 5), Westport quadrangle (No. 3), and Landes quadrangle (No. 4.), are being prepared by these geological surveys for use in planning river drainage work.

are situated on a railroad, although a new railroad, planned to connect Oblong and Bridgeport is completed from Oblong to Hardinville.

Altho this is chiefly an agricultural region, probably the greatest commercial interest centers in the development of the oil fields in this area, which now constitute the main part of the Southeastern Illinois Oil field. The region in which the oil is found has a width of from three to five miles, and, entering the area at the north just east of Oblong, it extends in a direction a little east of south the entire length of the Hardinville quadrangle, and continues near the eastern border of the Sumner quadrangle to as far south as three miles below Bridgeport.[1] This area is a part of the Crawford and Lawrence county oil fields, which, in 1910, produced over eighty-five per cent of the total petroleum output of Illinois. The production of these two counties alone was sufficient to place Illinois in the third rank as an oil producing state.[2] Illinois still ranked third in the production of petroleum for 1912, but no information was obtainable as to the relative importance of these fields, altho

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[1] For a full description of these oil fields see Bulletin No. 2, Ill. State Geol. Survey, The Petroleum Industry of Southeastern Illinois, by W. S. Blatchley, 1906, and Bull, No. 16, Ill. S. Geol. Survey, pp. 42-176, on The Oil Resources of Illinois, by R. S. Blatchley, 1910; also a short article by R. S. Blatchley, on The Structural Relations of the Oil Fields of Crawford and Lawrence Counties, Illinois, in Economic Geology, Vol. VII, No. 6, September, 1912, pp. 574-582.

[2] Mineral Resources for 1910, U. S. Geol. Survey, 1911, Pt. II, pp. 330, and 345.

they probably continue to yield the greater part of the total production of the state. A part of these oil fields, however, lies outside of the area under discussion.

SCOPE AND PURPOSE OF REPORT.

This report is based on records of about 1,100 water wells collected by the writer during the summer of 1912 under the direction of, and in connection with stratigraphical work done by T. E. Savage for the Illinois State Geological Survey. The purpose of the work was three-fold: First, to gain all possible information concerning the stratigraphy of the rock formations of the area, which might be secured from records of wells entering rock. In this way, any easily recognizable formations, especially coal beds, might be traced and mapped in areas where heavy mantles of glacial drift prevented the study of the rocks in actual outcrops. Second, to make a study of the underground waters and the water-bearing layers of the area, especially those of the Pleistocene deposits, with especial reference to the geological relations of the various water-bearing formations. And third, to study the configuration of the pre-glacial rock surface of the region, which may best be determined by constructing a map made by plotting the elevations of the rock surface at different points, as found in the wells.

With the exception of wells furnishing water for power-houses in the oil fields, nearly all of the wells in the area are dug wells, only a few of which enter the solid rock, the most of them obtaining water from porous beds in the drift. This report, therefore, will deal mainly with information derived from the shallow drift wells of the area. As the field work was done under the direction of Professor T. E. Savage while he was collecting data for a cooperative report to be published by the Illinois State Geological Survey and the United States Geological Survey, some points which might properly find a place in a report of this nature have been discussed only slightly or have been entirely omitted. This is especially true of a detailed discussion of the surface features of the glacial drift, or of the hard rock geology of the region.

An effort was made to get information in such a manner that there would in no case be a distance of more than one mile between wells furnishing data, and if possible, to secure data from places not more than three-fourths of a mile apart. In some parts of the region, as on the bottom lands along the Embarass River, this plan could not be followed, as considerable areas of such lands are not yet cultivated. The schedule followed in collecting the well records included the following points:

1. Elevation of the surface at the top of the well.

2. Depth of the well, and depth to water in the well, measured whenever possible.

3. Depth to solid rock, if it was reached.

4. Depth to, and thickness of, the water-bearing bed.

5. Nature of the water-bearing bed--sand, gravel, rock, or clay.

6. Position of water-bearing sand or gravel beds with reference to beds of clay (till) or to the underlying rock.

7. The presence or absence in the till, of any black, mucky, or peaty layer with wood fragments. If any such bed was found, its relation to the beds above and below it was noted.

8. The making of a detailed log or section of the kinds and thickness of the different materials passed through in putting down the well.

For various reasons, the best information that could be obtained in a number of cases was very meagre, and at some places the only data which could be secured was the depth of the well, and the depth to the water, both of which were obtained by measurement.

A part of the travelling in the field was done on a motorcycle, while a horse and buggy were used when the roads were in bad condition. Altho no thoro comparative test of the economy of these two methods of travel was carried out, it is believed that the motorcycle may prove the cheaper and more rapid means of covering the field when doing such work as collecting well records in a region that is comparatively level.

ACKNOWLEDGMENTS.

The writer wishes to express his obligations to Mr. F. W. DeWolf, Director of the Illinois State Geological Survey, for permission to use, as a basis for this report, data which was collected at the expense of the State Survey, and for many other kindness shown at various times; and to Professor T. E. Savage,

under whose direction the work was done, for the many helpful suggestions offered, both in the field and in the preparation of the report. The writer has also been greatly aided by having free access to the many records of oil wells in the region collected at various times by R. S. Blatchley in connection with his studies of the oil fields for the State Survey.

Liberal use has been made of publications, both of the United States Geological Survey, of the Illinois State Geological Survey, and of other reports, in the preparation of the paper, especially in connection with that part dealing with the hard rock geology of the region, and the general relations of the underground waters. In the bibliography at the end of this report the writer has listed the more important publications bearing on the subject of the paper, and consulted in its preparation.

P H Y S I O G R A P H Y .

GENERAL TOPOGRAPHY.

Relief.

The maximum relief of the surface in the Hardinville-Sumner area is slightly over 250 feet. The highest point in the two quadrangles is found in Sec. 34, T. 4 N., R. 13 W.,[1] where the elevation is 641 feet above sea level. There is only one other place in the area where the elevation is above 600 feet. This is in Sec. 29, T. 4 N., R. 14 W., at which place is located a triangulation station of the Lake Survey and Coast and Geodetic Survey. The lowest point in the region studied is along the south boundary of the Sumner quadrangle, where Bonpas Creek leaves the area in Sec. 22, T. 1 N., R. 14 W., the elevation of the water level of the creek at this place being about 385 feet. The distance between these points of highest and lowest elevation is about twenty miles, and the average slope is about seventeen feet per mile, The land surface, however, does not slope uniformly between the two points. Probably the steepest gradient in the entire region is found in the N. W. ¼, Sec. 15, T. 1 N., R. 13 W., where there is a difference of more than 100 feet in a distance of about one-eighth of a mile.

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[1] Township numbers in this region refer to the Second Principle Meridian, located in Indiana. For a map showing the principle meridians and base lines governing Illinois land divisions, see Leverett, Frank, The Illinois glacial lobe: Monograph vol. 38, U. S. Geol. Survey, 1899, pl. II.

Physical Features of the Hardinville Quadrangle.

In a discussion of the topography of the area the features of each quadrangle may well be considered separately. The Hardinville quadrangle is roughly divided into two parts by the Embarass River, which enters the area on the west side, about five miles south of the north boundary of the quadrangle, and meanders southward near the west border for about four miles. It then turns at an acute angle and trends northeast to a point about two miles north of the center of the quadrangle, where it again bends toward the southeast. Just before reaching the eastern boundary of the area it again turns rather abruptly to the south, and follows a course nearly parallel with the east line of the quadrangle to the place where it leaves the region three miles north of the southeast corner.

Bordering the Embarass River is a belt of lowland or flood-plain one to six miles wide, which is subject to overflow during times of high water. The river flows in a channel cut from five to twenty feet below the general surface of the flood-plain, which is extremely flat over a large area, in many places not varying more than two or three feet in elevation in distances of one or more miles. The average elevation of the flood-plain is about 435 feet above sea level. In many places the river has formed a natural levee two to five feet higher adjacent to the river channel than at a distance of one-fourth to one-half mile away. In some places it has been necessary to build artificial levees to protect the land from overflow, as in the region just south of Westport on the east side of the river.

The upland surface on either side of the Embarass generally rises away from the river, with an average gradient of about fifteen feet per mile. Probably the most notable exception is a small area north of the river, along the east side of the quadrangle, which is much rougher and higher than the surrounding country, where, in a distance of two miles, the surface rises from an elevation of about 420 feet at the river to over 580 feet above the sea in Sec. 7, T. 5 N., R. 12 W., giving it a slope of about eighty feet per mile. South of the Embarass the gentle slope of the surface is broken on the west side of the quadrangle by a ridge the north end of which at the river is one mile wide, but it becomes wider toward the south. Near the southern boundary of the quadrangle the upland becomes more broken and the slopes are steeper.

Along the east side of the quadrangle the level of the upland areas south and southwest of the river, and the rougher region north of the river are evidently the result of the resistant character of the pre-glacial rock formations. In these places, where the topography is dominated by the underlying rock, the greater part of the surface has been reached by the streams, and the erosion cycle may be said to have reached a stage of maturity. On the other hand, in the areas where the surface has a more gentle slope, the rock surface lies under a considerable thickness of drift, as will be shown in a later part of this paper. In the erosional process since the glacial period, the Embarass has almost reached its base-level, and is now meandering over a broad floodplain which is submerged during times of high water. Most of the area on either side of the river, except the places noted above, are also approaching base-level, and thus a large part of the Hardinville quadrangle may be said to be in a stage of late topographic maturity.

Physical Features of the Sumner Quadrangle.

Taken as a whole, the topography of the Sumner quadrangle is quite different from that of the area immediately north. The loose mantle of Pleistocene materials is thinner over a considerably larger area than in the Hardinville quadrangle, and hence the underlying rock is more important in the development of the topography, and the land surface is more rugged than in the Hardinville quadrangle. There are three areas, however, in which this statement will not hold true. The principal streams in the quadrangle, Bonpas Creek and Little Bonpas Creek, Catfish Creek, and Raccoon Creek, as will be described later, are flowing in pre-glacial valleys, and the rock surface, under the floodplains of these streams, is buried to a much greater depth than elsewhere in the quadrangle, the result being a smooth type of topography over the lowland areas.

Excluding these flood-plain areas, the topography of the greater part of the quadrangle is controlled by the pre-glacial rock surface. An irregular ridge extends approximately due north and south near the middle of the Sumner area, becoming less prominent at the north end of the quadrangle where it expands into a wider upland toward the west. In only one or two places does the surface elevation of this belt fall below 500 feet, and in some places, the altitude reaches 550 feet or more. There is also an area along the north side of the quadrangle, just east of the middle, where an elevation of 641 feet is reached, which is the highest point in the entire region. (see p. 8) There is also a small area in the northwestern part of the quadrangle which stands considerably above the general level of the upland. The uplands of the Sumner quadrangle are usually much dissected, especially at the extreme north and south ends, in places being quite rough. The streams have worked headward until only a few areas of level prairie upland remain and these are of small size. The greater part of the Sumner quadrangle is in a mature stage of the erosion cycle, but seems not quite so advanced as that of the Hardinville quadrangle.

DRAINAGE.

All of the streams in the Hardinville-Sumner area are tributary to the Wabash River. The major stream of the Hardinville quadrangle is the Embarass River, which rises 100 miles to the north, in Champaign county, and flows south and southeast, joining the Wabash about ten miles southeast of Bridgeport. The river is flowing in a pre-glacial valley throughout the greater part of its course, as will be shown in a later discussion of the pre-glacial rock surface. This river and its branches have well developed flood-plains, and many acres of land bordering the streams are subject to overflow during high water. Over considerable areas between Chauncey and Westport, and south of the latter town, the water frequently covers the surface to a depth of three or four feet. Plans are being made for the improvement of the river, so as to prevent such great damage from overflows.

The main tributaries of the Embarass are Honey Creek, Big Creek, and the North Fork of the Embarass on the north, and Muddy Creek, Eagle Branch, and the Slough on the south. The gradient of all of these streams is gentle and their currents are correspondingly sluggish. This is especially true of the two streams last named. A number of drainage ditches have been dug, or are in course of construction, or are being planned, to aid in the improvement of the bottomland, a large part of which is not under cultivation.

The drainage of the Sumner quadrangle, in contrast to that of the Hardinville, is not dominated by any one large stream. Along the entire north border of the quadrangle tributaries of Muddy Creek enter from the Hardinville area. The longest branch, Crabapple Creek, extends for a distance of five miles from the north boundary of the Sumner quadrangle. The eastern side of the quadrangle is drained principally by Raccoon Creek, which flows nearly due south from the Baltimore and Ohio Southwestern Railroad two miles west of Bridgeport, until it reaches a point about one mile north of the south boundary of Lawrence county, where it bends abruptly and flows in an eastward direction out of the quadrangle, joining the Wabash River further to the southeast. The southeast corner of the area is drained by Crawfish Creek, a small tributary of the Wabash.

The largest stream in the Sumner quadrangle is Bonpas Creek, which rises in the northwest corner of the area, north of the town of Claremont, and flows nearly due south for its entire length, joining the Wabash near Grayville, about 16 miles south of the south boundary of the quadrangle. With its two main branches, Little Bonpas Creek, and Jordan Creek, it drains more than one-half of this area. For more than half of their length in the quadrangle, Bonpas Creek, and Little Bonpas and Jordan Creeks flow in a well developed flood-plain, one-half to two miles in width. The channels of Crawfish, Raccoon, and Muddy Creeks are also bordered by flood-plains of like width. The larger streams of the Sumner quadrangle, like those of the Hardinville area, are generally following lines of pre-glacial drainage.

GENERAL GEOLOGY.

GENERAL STATEMENT.

The writer devoted all of his time in the field to collecting well records which were to be used by T. E. Savage in the compilation of a detailed report on the Hardinville-Sumner area. No attempt will be made, therefore, to give more than a general outline of the geologic formations older than the Pleistocene. Until the summer of 1912 no detailed work had been done on the geology of the region outside of the oil fields. Brief reports of the geology by counties have, however, been published in the early reports of the Illinois Geological Survey.[1]

The succession of the geologic formations that have been explored by deep drilling in this region is as follows:

Period	Stage	Thickness
Recent		0-25 feet, average 5 feet.
Pleistocene		0-125 feet, average 25 feet.
Pennsylvanian	McLeansboro	480 ±
	Carbondale	300 ±
	Pottsville	300-600
Mississippian	Chester	300-400
	St. Genevieve	50-100
	St. Louis, Osage?	1000 +

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[1]Worthen, A. H., Geological Survey of Illinois, Vol. VI, 1875, pp. 22-62. The following discussion on the general geology of the area is based largely on the references given in note 1, bottom p. 3.

Practically all of the hard rocks of the region are covered with a mantle of glacial drift of Illinoian age which varies in thickness from a few inches to 100 feet or more. The rock formations are exposed only on the sides of the smaller valleys or in stream channels where they have been uncovered by erosion, and hence it is difficult to get a continuous exposure for any considerable distance. However, the records of a large number of deep wells in the oil fields along the east side of the area, and a few prospect holes in the region outside of the oil producing district, have furnished much information concerning the rocks to a depth of several hundred feet beneath the surface.

The hard rocks penetrated consist of Pennsylvanian and Mississippian strata, and are overlain by unconsolidated glacial drift and Recent alluvial deposits. The oil wells in Crawford county do not reach the Mississippian rocks, not passing entirely thru the Pennsylvanian. Those of the oil fields south of the Embarass River, however, enter the Mississippian series, usually penetrating these rocks to a depth of about 475 feet. One of the deepest wells in Lawrence county has a depth of 2,936 feet, and penetrated more than 1,300 feet of Mississippian strata.

MISSISSIPPIAN FORMATION.

The lowest strata explored belong to the Mississippian series and consist of the Chester, St. Genevieve, St. Louis and probably the Osage formations. The Chester formation, which includes the Birdsville, Tribune, and Cypress beds, averages about 365 feet in thickness. It is composed of variable strata of shale, limestone, and sandstone, usually with one or more thin beds of red rock, and red or pink shale. Beneath the Chester lies the St. Genevieve limestone from 50 to 85 feet thick, which is oolitic at certain levels. The St. Louis limestone is the lowest formation generally reached in the deeper borings, and is usually penetrated for only a few feet, but one well was drilled in limestone for more than 900 feet below the Cypress sandstone. This, however, probably included some of the Osage series, for in the records it is very hard to separate the St. Louis from the underlying Keokuk formation. On account of their great thickness the St. Louis and underlying limestones are known as the "Big Lime".

PENNSYLVANIAN FORMATION.

The Pennsylvanian strata in this region comprises the McLeansboro, the Carbondale, and the Pottsville formations. The McCleansboro is here about 480 feet thick, the Carbondale about 300 feet, and the Pottsville about 100 feet. The McLeansboro and Carbondale formations are principally shales, with varying lenses of sandstone, limestone, and coal. The Pottsville rocks are principally sandstones, in places grading into shaly sandstones or shales.

PLEISTOCENE AND RECENT FORMATIONS.

After the deposition of the Pennsylvanian rocks in this region, the area emerged from the sea, and a long period of erosion followed, until the surface became quite irregular. The eroded surface of the Pennsylvanian rocks is now covered by a mantle of glacial drift and Recent alluvial deposits which varies in thickness from a few inches on some of the higher ridges to more than 100 feet in some parts of the valley of the Embarass River. It is possible that in the deeper portions of the latter valley some pre-Pleistocene alluvial material that was not disturbed by the ice sheet may occur between the glacial drift and the Pennsylvanian rocks. The main body of drift in this region is of Illinoian age[1]. The Illinoian till is in some places covered by a fine silt, known as loess, which is post-Illinoian in age, but older than the Recent alluvial deposits. The loess, which may once have been continuous over the entire area, has in some places been eroded, and is now found only in patches. The youngest deposits in the region are Recent alluvial sediments, composed largely of clay, sand, and gravel, and occur only in the valleys of the larger streams where they were deposited from the water during times of overflow. Sand dunes of post-Illinoian age are found scattered over the flood-plain of Embarass River. The nature and distribution of the Pleistocene and Recent deposits will be considered more fully in a later part of this report.

The following record of an oil well put down on the Childress farm in Sec. 24, T. 4 N., R. 13 W., will show the succession of strata, and the character of the rocks in this region.

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[1] Leverett, Frank, The Illinois Glacial Lobe: Mon. U. S. Geol. Survey vol. 38, 1899, p. 25 and plate VI.

RECORD OF WELL NO. 3, ON CHILDRESS FARM.

RECENT AND PLEISTOCENE.

		Thickness	Depth
1.	Quicksand, white, soft	50	50

PENNSYLVANIAN-COAL MEASURES.

McLeansboro-Carbondale

		Thickness	Depth
2.	Sandstone, limestone, and shale, white and black	220	270
3.	Limestone, white, hard	15	285
4.	Shale and limestone, white, soft	135	420
5.	Coal and shale, black, soft	13	433
6.	Shale and limestone, white, soft	52	485
7.	Shale, brown, soft	10	495
8.	Sandstone, white, soft	35	530
9.	Shale, black, soft	10	540
10.	Shale, white, soft	95	635
11.	Coal, soft	7	642
12.	Shale, brown	133	775
13.	Limestone, white, hard	25	800
14.	Red rock, soft	10	810
15.	Shale, white, hard and soft	30	840
16.	Limestone, white, hard	10	850
17.	Shale, black	130	980

Pottsville

		Thickness	Depth
18.	Sandy limestone, white	40	1020
19.	Sandstone, white	170	1190
20.	Sandstone, white, soft	45	1235
21.	Sandstone, brown	60	1295

MISSISSIPPIAN

Chester

		Thickness	Depth
22.	Sandy limestone, brown, hard	20	1315
23.	Shale, brown	20	1335
24.	Shale and sandstone, white	55	1380
25.	Limestone, white, hard	25	1405
26.	Shale, white	15	1420
27.	Red rock, soft	7	1427
28.	Shale, black, soft	13	1440
29.	Sandstone, white, hard	14	1454

30.	Sandstone, white, soft	30	1484
31.	Shale, white, soft	16	1500
32.	Red shale, soft	8	1508
33.	Shale, white, soft	8	1516
34.	Sandstone, white, hard	4	1520
35.	Sandstone, white, soft	50	1570
36.	Shale, black, soft	50	1620
37.	Limestone, white, hard	5	1625
38.	Sandy shale, white, soft	25	1650
39.	Red rock, soft	8	1658
40.	Limestone, white, hard	8	1666
41.	Sandstone, white, hard	29	1695
42.	Shale, black, soft	37	1732
	St. Genevieve		
43.	Limestone, white, hard	44	1776
44.	Sandstone, white	7	1783

Small show of oil at 1520-1560
Oil at 1666-1695
Salt water at 1781
This well did not enter the St. Louis limestone.

ECONOMIC GEOLOGY.

Oil and Gas.

The economic products of greatest importance in the Hardinville-Sumner area are petroleum and natural gas. The oil and gas are found in several different formations known as oil sands. In Crawford county the oil sands lie at or near the top of the Pottsville rocks. The best producing sand, known locally as the Robinson sand, lies at a depth of about 875 feet, and is usually divided into two or three lenses which vary in thickness, oftentimes merging into each other, and sometimes being entirely absent. The distribution of the oil in Crawford county is governed by an anticline which trends slightly from northwest to southeast.

In Lawrence county there are a number of oil producing sands, the uppermost of which is probably in the McLeansboro formation. The Pottsville formation contains the Bridgeport sand in the upper part, probably corresponding to the Robinson sand of Crawford county, and in the lower part is the Buchanan sand. The underlying Mississippian rocks contain the most important oil producing sands in the county. The Chester strata include three sands, known locally as the "Gas", Kirkwood, and Tracey, while the St. Genevieve limestone contains the McCloskey sand. The McCloskey is one of the most important oil sands in the Illinois fields, as it furnishes a large initial production, and the yield is steady and long continued.

Coal.

Thin seams of coal are found in a number of places in the region. In the Hardinville quadrangle coal was reported in a total of fifteen wells. Briefly, the areas where the coal was found are as follows: along the east side of the quadrangle north of the Embarass River in Honey Creek township, in the upland area in the southwest part of Robinson township, in the uplands near the southwest corner of the quadrangle, and in the uplands in the southwest part of Petty township.

In the Sumner quadrangle coal was found in a somewhat larger number of wells, the total being forty-three. These are scattered in many places over the quadrangle, but are found most generally in the upland areas. Coal outcrops in a number of places along Bonpas Creek, where it has been mined for local use by the farmers, usually being dug out of the stream bank, no shaft being necessary. Near the southeast corner of the quadrangle there is also a fairly uniform seam of coal, about three and one-half feet thick, with a sandstone roof, found at a depth of 35 to 40 feet. During the summer of 1912 coal was mined from this seam at a place one mile east of Friendsville. In all of the places mentioned above the coal has been reported at depths varying from 5 to 100 feet, and the thickness of the beds is from a few inches to 7 feet. In this region the surface has been so trenched by erosion in pre-glacial time, and later covered with drift, that it is almost impossible to follow any specific coal seam for any considerable distance. As the coal seams are not continuous over any large area they can not be profitably worked on a commerical scale. Deep well drillings, however, have revealed the presence of good seams of coal at greater depths, varying from 200 to 600 feet below the surface, and it is quite possible that in the future, when coal can be profitably mined at depths greater than is done at present, this region will become important in the production of coal.

Other Economic Products.

In some places sandstone and limestone have been quarried on a small scale for local use in building and road making operations. Worthen[1] notes also that limestone was burned in the

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[1] Loc. cit. p. 49.

early days in this region for lime, but no kilns exist at the present time.

At a few places in the region clay from the Pleistocene deposits is used in the manufacture of common grades of brick and tile. A plant for brick-making is located at the town of Oblong, and two clay-working plants are operated at West Salem, in the southwest corner of the area. Along the Embarass River and other of the larger streams sand and gravel is available for concrete work and road building materials.

PRE-PLEISTOCENE ROCK SURFACE AND ITS RELATION TO THE PRESENT SURFACE.

PRELIMINARY STATEMENT.

Since the uplift of this region at the close of the Pennsylvanian period it has remained above the sea so far as is known. If it was submerged at any time during the Mesozoic and Cenozoic times, all evidences of the rocks deposited during that submergence have been destroyed. Evidences in other parts of the state, however, point toward a continual land surface during the entire geologic time since the Pennsylvanian. During this long period erosional processes have been active, and just before the advent of the great Pleistocene ice sheet the surface was very much dissected.

CONTOUR MAP OF PRE-GLACIAL ROCK SURFACE.

It was one of the objects of this paper to study the configuration of this pre-Pleistocene rock surface. In making this study contour maps were constructed which show the approximate topography of the old rock surface in the same manner that the topographic map shows by contour lines the configuration of the present surface. In making this map all available data concerning the elevation of the rock, as determined either in outcrop, or from water-well records, was plotted on maps of the two quadrangles shown in Plates II and III. On the assumption that the rock surface sloped uniformly between any two points on which information was obtained, contour lines were drawn passing thru all places at which the rock surface was at the same level. The contour interval is twenty-five feet, using mean sea level as the datum plane.

Possible Errors in Construction of Map.

The configuration of the rock surface has been shown only in a general way, owing to a number of reasons. In the first place, in many parts of the region studied, the data concerning the depth to the rock surface was very meagre, and in some areas no information could be secured. Hence there are places where the location of the contours is a matter of conjecture. In such places the contour lines are broken and their position is based on conditions found in the immediate vicinity.

Another factor which may lead to error in making the map is the assumption that the rock surface slopes uniformly between any two points of known elevations. A concrete example may illustrate this possibility of error. At the house on the south side of the road, one-fourth mile east of the northwest corner of Sec. 2, T. 4 N., R. 14 W., in the Hardinville quadrangle, rock was reached at an elevation of 469 feet above sea level. On the top of the hill approximately one mile west of this place the elevation of the rock is 530 feet. No data was secured for the intervening distance. The difference in elevation is 61 feet, and the distance is nine-tenths of a mile. If the rock surface sloped uniformly, the gradient would be approximately 7 feet for each tenth of a mile. According to this the 525 foot rock surface contour would cross the east-west road just under the figure "4" in the elevation "546"(at the road corner at the top of the hill) and the 500 foot rock surface contour would cross the road under the figure "4" of the elevation "491" (just west of Asbury church). Obviously this is impossible since the elevation of the land as shown by the topographic map is below the elevations given for the rock surface at the respective locations. In such cases as this it was necessary to draw the contours of the rock surface in such a way as to be consistent with the topographic map. In doing this it is easily seen that their position becomes somewhat conjectural.

Other sudden changes in the slope of the rock surface may, in cases like that mentioned above, occur in places where the thickness of the drift has obliterated all evidence which might be shown by the surface topography. For example, the depth to rock at different places over the flood-plain of the Embarass River between Chauncey and Westport is found to vary from 50 to 100 feet or more, while the flood-plain surface is practically flat. In this case we have no surface indication of any sudden changes in the rock surface, which we know from our knowledge of any dissected topography must exist. We must, therefore, depend entirely on well records, which in this particular locality are not always reliable, and the liklihood of error is considerable.

Another difficulty encountered was the inability of many of the farmers to distinguish between partially consolidated or cemented drift, sand, or gravel beds, and the pre-glacial rock. For instance, in the region north of the Embarass River, some parts of the drift have been partially cemented, and are known locally as "cement rock". In a number of cases this "cement", which is sometimes called hardpan, was reported as being solid rock, altho further questioning of the informer revealed the fact that it was merely an indurated phase of the glacial drift. It is quite possible, therefore, that some errors may have crept in from this source, altho, wherever there was any reason to doubt the existence of rock, if reported, an attempt was made to gain satisfactory information on that point.

DETAILED DESCRIPTION.

Pre-glacial Surface of the Hardinville Quadrangle.

ROCK SURFACE NORTH OF EMBARASS RIVER.--In the region north of the Embarass River in the Hardinville quadrangle only a very few wells are dug or drilled to rock. These constitute approximately 23 per cent of the wells visited in the north half of the area, and of the number which report rock at least two thirds of them are located east of the middle line of the quadrangle. As the west and southwest portions of this northeast quarter of the quadrangle lie in the oil fields, an attempt was made to secure the desired data from records of oil wells put down in this region. Practically none of these were detailed logs, but many of them gave the length of the first set of well-casing or drive-pipe which is usually put in soon after the first solid rock is reached. This first casing may be set into the rock from one to ten or more feet, but unless the rock is quite soft the distance is generally less than ten feet. In plotting the data from the skeleton logs five feet was subtracted from the depth to rock as given. It was thought that in this way error might be lessened, for if the casing was set in the rock only a few inches the elevation would be but five feet too high, while on the other hand, if it was put in ten feet, the elevation would be only five feet too low. Of course in some cases it is likely that the error was slightly greater than this, but in plotting the contours, the writer tried to use as much care as possible in the selection of critical points, and wherever there seemed to be any marked difference in elevation, only the highest points in the immediate neighborhood were used, for they showed that the rock was at least as high as the figures used since the casing is not put in until the rock is reached. It will readily be seen that at best the resulting map in this part of the region is an approximation, but the writer believes that it will give a good idea of the general pre-Pleistocene topography of the area.

As shown on plate II, the channel of Honey Creek, on the east side of the quadrangle, is superimposed on a rather deep valley which had the same general course as the present channel of the stream. The place where this old valley joined the Embarass River could not be determined. The bottom of this valley,

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TOPOGRAPHY

STATE OF ILLINOIS
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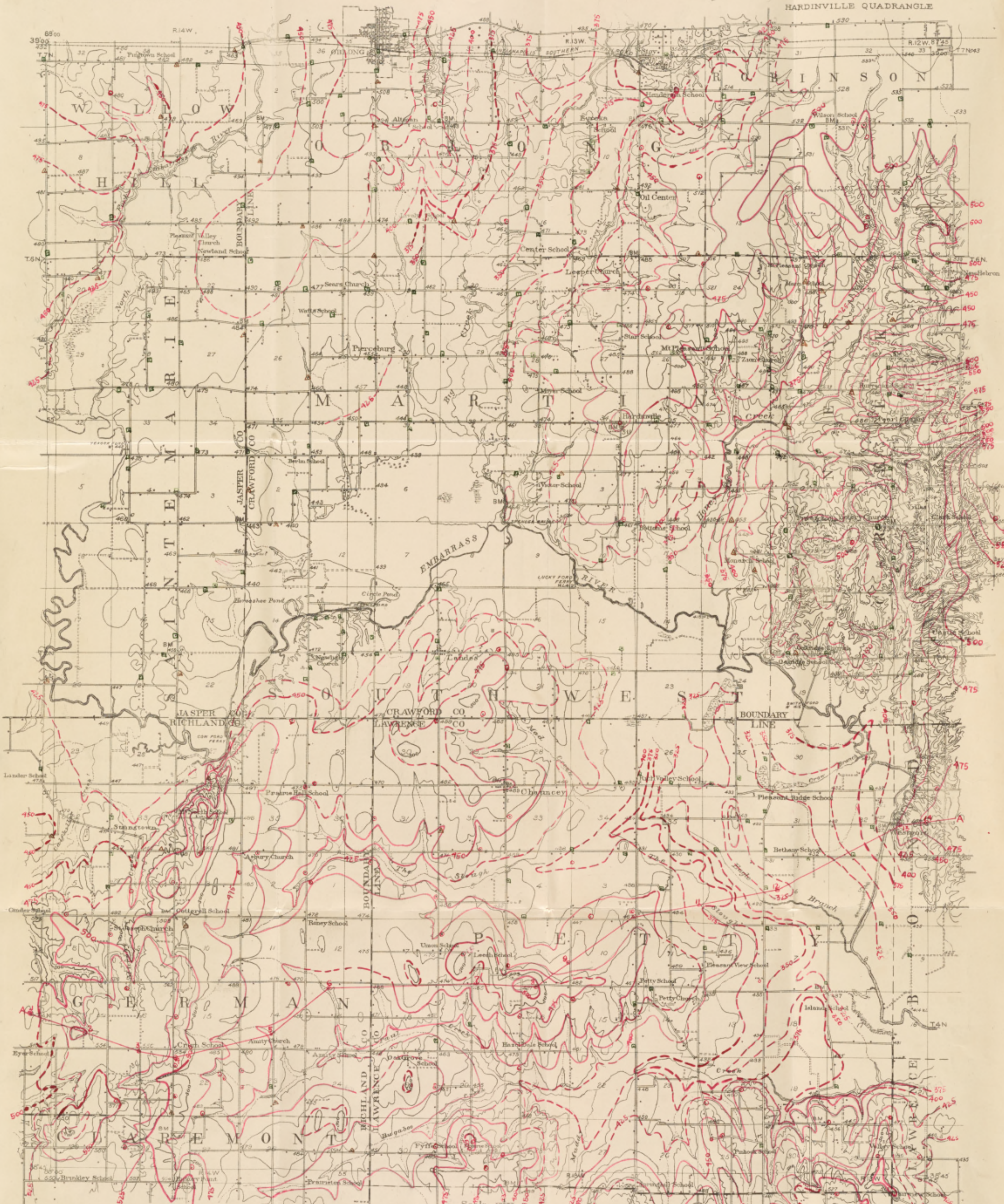
H. FOSTER BAIN, DIRECTOR STATE SURVEY

Advance sheet. Subject to correction.

Plate II.

ILLINOIS
HARDINVILLE QUADRANGLE



R. B. Marshall, Chief Geographer.
W. H. Herron, Geographer in charge.
Topography by J. F. McBeth, H. L. McDonald and Merrill Hackett.
Control by U.S. Lake Survey, J. R. Ellis and Henry Bucher.
Surveyed in 1907-8.
SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

Scale 1/48000

1 ½ 0 1 2 3 4 Miles

4000 2000 0 4000 8000 12000 16000 Feet

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

APPROXIMATE MEAN DECLINATION 1908

MAP SHOWING BY CONTOUR LINES THE CHARACTER OF THE PRE-GLACIAL ROCK SURFACE AND ALSO SHOWING THE DISTRIBUTION OF WELLS OBTAINING WATER FROM THE DIFFERENT KINDS OF WATER-BEARING STRATA.

LEGEND

- □ WELLS OBTAINING WATER FROM SAND OR GRAVEL.
- ○ WELLS OBTAINING WATER FROM ROCK.
- △ WELLS OBTAINING WATER FROM DRIFT CLAY.
- CONTOUR LINES OF ROCK SURFACE--CONTOUR INTERVAL 25 FEET, DATUM MEAN SEA LEVEL.

near its mouth, apparently is slightly less than 350 feet above sea level, the drift at that place being about 75 feet thick. The valley rises rapidly toward the northeast until we find rock outcropping along the banks af the present stream in Sec. 5, T., 6 N., R. 12 W., at an elevation of about 510 feet. The distance is about eight miles and the difference in elevation is about 150 feet, making the average gradient about 20 feet per mile. However, as the contours in the lower end of the valley are largely dependent on skeleton logs, the depth of the valley near the Embarass may be somewhat exaggerated.

East of this valley the rock surface rises to a heighth of over 575 feet, the heighest point being 584 feet above sea level, as recorded in a well on top of a hill in the south central part of Sec. 3, T. 5 N., R. 12 W., near the east edge of the map. This is the highest point in either quadrangle at which rock is known to occur. The drift at this place is 18 feet thick. The rock surface is considerably lower on the north side of this hill, falling below an elevation of 450 feet just south of New Hebron, and again rising above 500 feet a little farther north. The southern part of this upland to the east of the old Honey Creek valley is dissected by a smaller valley from the south. The divide between this valley and the Honey Creek valley reaches an altitude slightly above 500 feet, and is fairly level. Altho rock outcrops are frequent along the banks of this valley, the minuteness of the dissection of the present surface does not appear to be due to the presence of old rock channels, for the smaller ravines do not necessarily follow those of the pre-Pleistocene drainage, altho the larger valleys of the present surface do seem to coincide approximately with those of the old rock surface.

To the west of Honey Creek is a ridge which rises toward the northeast. This divide rises from an elevation of about 425 feet, at a point about one-half mile north of Lucky Ford (Sec. 10, T. 5 N., R. 13 W.) until it reaches an altitude of about 515 feet in Sec. 5, T. 6 N., R. 12 W. The town of Hardinville is situated on a small eminence which is apparently underlain by a low hill of ~~the~~ rock similar in outline to that shown on the topographic map.

West of this northeast-southwest ridge the data concerning the rock surface is very meager. Skeleton records of oil wells, however, seem to indicate the presence of a deep valley, the bottom of which, about one mile southwest of Stoy, is approximately 350 feet above the sea. The available data covers only the area east of a line drawn from Oblong to Hardinville. From the information in this part of the region, it seems probable that the main branch of Big Creek is following this old channel, while the two other principal branches, one entering from the vicinity of Oil Center, and the other from the direction of Oblong, are apparently superposed on the sides of the old valley. The thickness of the drift in this valley varies from about 100 feet in the bottom to 40 or 50 feet on the valley sides.

Practically no information concerning the rock surface was obtainable in the region west and southwest of Oblong, as most of the wells find water in sand or gravel before reaching rock. It seems quite probable, however, that another rock ridge lies between Big Creek and the North Fork of the Embarass River, and that another deep valley is present in the rock underlying the latter stream. In this west half of the upper part of the Hardinville quadrangle rock was reported at the first house north of the Berlin School, in Sec. 35, T. 6 N., R. 14 W., at an elevation of 409 feet; at a house just north of the center of Sec. 23, in the same township, at an elevation of 464 feet, and at the first house southeast of the Illinois Central railroad depot in Oblong at an elevation of 487 feet. Rock was also found west of the North Fork of the Embarass, at an elevation of 432 feet, in the southwest corner of the N. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$, Sec. 20, T. 6 N., R. 14 W.; at an elevation of 478 feet in the southeast corner of the N. W. $\frac{1}{4}$, N. W. $\frac{1}{4}$, Sec. 9, T. 6 N., R. 14 W.; and at an elevation of 468 feet in the northwest corner of the same section. Rock was also reported at an elevation of 461 feet at a house about one-fourth mile southwest of the Illinois Central bridge over the North Fork of the Embarass.

The depth to rock along the flood-plain of the Embarass River in the north half of the quadrangle is not known. Judging from information secured on the lowland in the southeast quarter of the quadrangle, the river is superposed on an old valley which is probably cut to a depth of from 325 to 350 feet above sea level. This view is corroborated by the statement of Leverett[1] that the course of the Embarass River is determined largely by a pre-glacial valley as far north as Newton, about 10 miles up-stream from the western boundary of the quadrangle, and possibly for a greater distance.

ROCK SURFACE SOUTH OF EMBARASS RIVER.--In that part of the Hardinville quadrangle south of the Embarass River, a larger number of the wells penetrate to rock. Approximately 45 per cent of all the records collected in this part of the area reported rock.

The most striking surface feature of this half of the quadrangle is the broad flood-plain bordering the Embarass. Here, as in some parts of the region north of the river, the data secured gave little information concerning the rock surface. No domestic wells are known to reach the rock, abundant water supply being found in sand or gravel at depths of 10 to 30 feet, while the rock is in most cases many feet lower. A few detailed oil well records gave definite information as to the depth to rock, but most of the data in the area of the flood-plain was secured from skeleton logs. No records of the rock surface were obtained from the region lying between the river, and a line drawn from Smith Ford (Sec. 19, T. 5 N., R. 12 W.) and the northwest corner of Sec. 8, T. 4 N., R. 12 W.

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[1]Loc. cit. P. 535.

The skeleton records indicate that the flood-plain of the Embarass overlies a deep valley with rather steep sides, the elevation of the bottom of which is between 300 and 325 feet above sea, or nearly 125 feet below the present surface, as shown on plate II. According to these logs, there are low rock islands or monadnocks in this valley, one covering parts of Sec. 36, T. 5 N., R. 13 W., Sec. 1, T. 4 N., R. 13 W., and Sec. 6, T. 4 N., R. 12 W.; and another one occupying the west half of Sec. 25, T. 5 N., R. 13 W.

As mentioned previously, most of the information used in plotting the contours in this vicinity was secured from skeleton logs, so that the great thickness of the drift may be slightly exaggerated. However, a detailed log of well no. 1 on the Hipshire farm in the southwest corner of the S. W. $\frac{1}{4}$, N. W. $\frac{1}{4}$, Sec. 6, T. 4 N., R. 12 W., having a surface elevation of 436 feet, indicates a thickness of 100 feet of Pleistocene material above the rock, and shows the elevation of the rock as low as 336 feet. More light will be thrown on the depth of this pre-glacial valley as more detailed records are secured.

Two prominent channels branch off from the main valley of the pre-Pleistocene Embarass River, having the same general courses as the valleys of Muddy Creek and its branches, and The Slough, of the present drainage system. These ancient valleys were cut thru a ridge extending north and south across the middle of the quadrangle. The old valley of Paul Creek was narrower than that of the old valley of The Slough, just as is the case at present.

Three isolated areas of present highland represent remnants of an earlier pre-Pleistocene ridge. The summit of the most southerly of these rock ridges is near the Prairie school, in the center of Sec. 29, T. 4 N., R. 13 W., where the rock is found at an elevation of 505 feet. Farther north, in the middle of the north side of Sec. 16, in the same township, the ridge reaches an elevation of 518 feet, the drift at this point being only 6 feet thick. The third remnant is somewhat lower than the other two, the highest rock being recorded in the southwest corner of the S. E. $\frac{1}{4}$, Sec. 20, T. 5 N., R. 13 W., where the elevation is 486 feet. It is probable that the rock may reach a higher altitude in the highest parts of the upland shown on the topographic map. The town of Chauncey is located near the southeastern portion of this ridge.

West of the remnants of the old ridge the pre-glacial valleys widen out both to the north and to the south as do the present valleys. There are here three quite extensive comparatively flat areas over which the elevation of the rock surface is between 450 and 475 feet. Along the west border of the quadrangle the rock surface again rises above the general level of the present land surface. Just south of the Embarass River this is shown by a very sharp ridge about 100 yards wide at the top, and less than half a mile wide at the base, with steep sides, the rock surface at one place on the east side rising 58 feet in less than 150 yards. The highest recorded elevation of the rock at the north end of the ridge is 539 feet, in an outcrop on the east side of the hill along the road between sections 27 and 34, R. 5 N., R. 14 W.

Farther south the ridge becomes considerably broader, so that two miles north of the south boundary of the quadrangle it is nearly level and about one and one-half miles in width. The rock reaches an elevation of 560 feet above sea level on the south side of the S. W. $\frac{1}{4}$, Sec. 20, T. 4 N., R. 14 W., this being the highest point recorded in the quadrangle south of the Embarass River. It is quite probable that an altitude of 575 feet is reached on the hill a short distance south of this place. The rock surface apparently slopes toward the west in the region beyond the west boundary of the quadrangle.

The thickness of the drift overlying the rock in the southern half of the Hardinville quadrangle, with the exception of the flood-plain of the Embarass, varies from 5 feet or less to about 30 feet, the average being near 15 feet. The greatest thickness is over the lowlands, such as that between the two ridges in the west part of the region. On the other hand, rock is frequently seen outcropping on the uplands.

The position of the lowland area mentioned above presents quite an interesting problem, being elongated parallel to two rock ridges, and at right angles to the present drainage lines. There seem to be two plausible explanations of this long trough, the first being that the drainage of this valley was originally northward into the Embarass, and that later streams worked their way westward from the lower part of the Embarass, and finally cut thru the east ridge and diverted the drainage in the direction assumed by the present streams. A second theory is that the widening of the old valleys into an elongated trough may be due to unequal resistance of the rock, possibly in conjunction with slight local folding of the strata. This latter theory is supported by the fact that in some of the wells in this vicinity at least one bed of very hard limestone, about 5 feet thick, is found, while the rock in other places is principally softer shale or sandstone. If the first mentioned theory applies we should expect to find the surface of the rock at the south end of the trough higher than at the north end near the Embarass River, and any branches of the youngest rock valleys which head southward should be more sharply defined than those coming from the north. However, any such topographic evidences might have been destroyed by extensive erosion after the diversion of the drainage. A small area about 25 feet above the surrounding country near the south end of the trough, together with 3 or 4 small hills elongated in a north and south direction might be considered as evidence of underlying erosion remnants of a northward drainage, if it be granted that these ridges are the surface expression of drift-covered rock hills. The experience gained by the writer in plotting the contours of the rock surface leads him to believe that such is the case, for many instances are found in which the contours follow the general outline of the drift surface to a large extent.

Pre-Glacial Surface of the Sumner Quadrangle.

The present topography of the Sumner quadrangle is controlled by the underlying rock to a much greater extent than was the case in the Hardinville quadrangle. In most places the drift is thinner than in the Hardinville quadrangle. Rock was reported in approximately 50 per cent of the wells visited in this quadrangle, a slight increase over the percentage for the Hardinville area.

The most prominent feature of the pre-Pleistocene topography of the Sumner quadrangle was a rock ridge running north and south, located just a little to the east of the middle of the area, as shown in plate III. Altho not quite in a direct line with the ridge in the middle of the Hardinville quadrangle, it is probably a general southward continuation of that elevation.

Along the north side of the quadrangle the ridge widens to the eastward reaching as far as Sec. 32, T. 4 N., R. 12 W. It is on this eastward extension that we find the greatest elevation of the rock surface recorded in the quadrangle, reported from the first house north of Union Chapel on the west side of Sec. 36, T. 4 N., R. 13 W., where the altitude of the rock is 564 feet above sea level, the thickness of the drift being 11 feet. The highest point of the present surface, 641 feet above the sea, is a little more than a mile northwest of this place. No information was obtained concerning the depth to rock on this hill, the nearest well furnishing data being at the house on the crest of the ridge in the S. E. $\frac{1}{4}$, Sec. 34, T. 4 N., R. 13 W., where the

TOPOGRAPHY

STATE OF ILLINOIS

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GEORGE OTIS SMITH, DIRECTOR

Advance sheet. Subject to correction.

Plate III.

ILLINOIS
SUMNER QUADRANGLE

R. B. Marshall, Chief Geographer
W. H. Herron, Geographer in charge
Topography by Frank Tweedy, L. L. Lee and J. B. Leavitt
Control by J. R. Ellis, W.A. Gelback and H. Bücher.
Surveyed in 1911

SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS

Scale $\frac{1}{48000}$

Contour interval 20 feet.

MAP SHOWING BY CONTOUR LINES THE CHARACTER OF THE PRE-GLACIAL ROCK SURFACE AND ALSO SHOWING THE DISTRIBUTION OF WELLS OBTAINING WATER FROM THE DIFFERENT KINDS OF WATER-BEARING STRATA.

LEGEND.

- □ WELLS OBTAINING WATER FROM SAND OR GRAVEL.
- ○ WELLS OBTAINING WATER FROM ROCK.
- △ WELLS OBTAINING WATER FROM DRIFT CLAY.
- CONTOUR LINES OF ROCK SURFACE--CONTOUR INTERVAL 25 FEET, DATUM MEAN SEA LEVEL.

surface elevation is about 583 feet. The well was said to be 40 feet deep, and did not reach solid rock. The water comes from quicksand at the bottom. The rock here must lie at an elevation of less than 543 feet, but the fact that there is quicksand at the bottom is an indication that the rock is probably only a few feet lower, since sand or gravel beds often occur just above the rock.

No outcrops were seen along the roads on the hill, and the drift at houses near its base on the west side was nearly 30 feet thick. It is therefore impossible to tell just how great an elevation the rock attains. It is certain, however, that the hill has a rock core as do all the other prominent elevations in this region. If the drift was as much as 40 feet thick on the top of the hill, (which seems improbable) the elevation of the rock surface would be at least 600 feet, which is higher than any other known rock surface in either quadrangle. Probably the rock actually reaches even a higher elevation than is shown on the map in plate III.

The rock ridge running thru the middle of the Sumner quadrangle is, on the whole, somewhat higher than that of the ridge in the Hardinville area. In only one place is its altitude less than 475 feet, and at a number of points it rises to an altitude of more than 525 feet. It is also in this ridge that the steepest gradient of the rock surface known in the entire area is found. This is at the first house north of the S. W. corner of section 10, T. 1 N., R. 13 W., where rock occurs at an elevation of 436 feet. Along the road running east and west thru the middle of the same quarter section, in a small gully just half way between Black Oak School and the west side of the section, an outcrop was also seen at an altitude of 510 feet. The difference in elevation is 74 feet, and the distance between the two points approximately one-fourth of a mile, making the gradient nearly 300 feet per mile. Altho this is the steepest gradient recorded, there are probably other places where the slopes are steeper. For instance, it is not unlikely that the descent of the rock surface is more rapid on the south side of the same valley above mentioned, since the part of this valley which is near the middle of the N. W. $\frac{1}{4}$, Sec. 15, T. 1 N. R. 13 W. was noticed as having the steepest surface gradient in either quadrangle (see p. 8).

The ridge in the Sumner area also differs from that in the more northern quadrangle in that no streams have cut thru it, altho in a number of instances gullies or ravines have developed headward from opposite directions, and have considerably lowered the divide formed by the ridge. The best instance of this is near the northeast corner of Sec. 10, and the northwest corner of Sec. 11, T. 1 N., R. 13 W., where the rock lies at an elevation of 472 feet, the drift being about 30 feet thick.

In pre-Pleistocene times there were, as at present, three main drainage basins in the east part of the quadrangle. The one farthest north is now occupied by a small stream, flowing thru the town of Bridgeport. According to skeleton records of oil wells, the rock surface in this valley in the S. W. $\frac{1}{4}$, Sec. 9, T. 3 N., R. 12 W. is as low as 355 feet above sea level, the drift according to these logs being 80 feet thick. These records show that this pre-glacial valley must have had a rather steep gradient, for it heads in the uplands 5 miles to the northwest, where the rock surface is 200 feet higher. However, about 2 miles distant, in the southeast corner of Sec. 6, T. 3 N., R. 12 W., the elevation of the rock is 524 feet.

A short distance south of Bridgeport a rock ridge reaches an altitude of nearly 500 feet, and serves as a divide between the rock valley just described and the ancient valley of Raccoon Creek. The drift here is about 20 feet thick.

The old rock valley of Raccoon Creek, as shown by the map, had the same general configuration as the present valley, being very wide, with a comparatively gentle gradient. Like the present valley, it was in danger of being beheaded by the stream mentioned, south of Bridgeport, which has the steeper gradient. In the same way, a part of its drainage basin on the south was being captured by the old Crawfish Creek valley, which also had a steeper gradient than did Raccoon Creek.

The map of the rock surface shows that during pre-Pleistocene times terrace-like rock platforms were present in a number of places along Raccoon Creek. The general outline of these terraces follows rather closely the contours of the topographic map, indicating similar flats on the present land surface. The thickness of the drift on these so-called terraces ranges from

10 to 25 feet, but the depth of the old valley of Raccoon Creek was not determined. A well at the house in the southeast corner of the N. E. $\frac{1}{4}$, Sec. 8, T. 2 N., R. 12 W., did not reach rock at a depth of 25 feet, the elevation of the bottom of the well being 408 feet. Another well near the center of the N. E. $\frac{1}{4}$, Sec. 29, T. 2 N., R. 12 W., did not reach rock at an elevation of 405 feet, while a third well in the same section, about one-fourth mile further southeast, reached rock at an altitude above 408 feet. It is evident that for some distance in the quadrangle the valley is less than 400 feet above sea level. It is quite possible, also, that during times of flood the water of the old stream flowed eastward thru the cut-off in the northern half of Sec. 16, and the south half of Sec. 9, T., 2 N., R. 12 W. A branch of Raccoon Creek now flows in this part of the valley, but an incomplete topographic map of the area just east of the Sumner quadrangle shows no appreciable divide between this branch valley and the lower part of the Raccoon valley a short distance east of the quadrangle. Since in other parts of the region the rock surface agrees so closely with the present topography, it seems probable that in times of high water during pre-Pleistocene epochs this place may have furnished an additional outlet to the waters.

Near the southeast corner of the quadrangle there is an old rock valley following the same general course of the present valley, of Crawfish Creek. It is separated from the old Raccoon Valley on the north by a divide which, in the S. W. $\frac{1}{4}$, Sec. 33, T. 2 N., R. 12 W., has an elevation slightly above 490 feet, the drift being about 15 feet thick. Crawfish Creek, with a steep gradient, had probably begun to divert some of the drainage of the old Raccoon Creek Valley before the advent of the ice sheet.

Concerning the depth of the Crawfish rock valley the best information obtained shows that rock was reached at an altitude of 380 feet in the S. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$, Sec. 18, T. 1 N., R. 12 W., where the thickness of the drift is 19 feet. Leverett[1] states that on the lowland 2 miles northeast of Friendsville wells 40 feet deep do not reach rock. However, he does not give any definite location or elevation of the wells. If we assume that these wells were located on the bottomland in the north-east corner of sec. 18, T. 1 N., R. 12 W., at an elevation of about 410 feet, the rock surface would lie at an altitude of less than 375 feet--somewhat lower than that shown on the map.

In the northwest quarter of the Sumner quadrangle there is another rock ridge, which is broader than the one extending across the middle of the area. It trends southeast until near the southeast corner of Claremont township, where it turns southward. This is a continuation of the ridge near the west side of the Hardinville quadrangle, and was also once connected with the ridge extending near the middle of the Hardinville area, and also with that across the middle of the Sumner quadrangle. Before the advent of the Illinoian ice sheet it was partially separated from the ridge in the Hardinville quadrangle by the streams that occupied the pre-Pleistocene valleys of Shurley Creek and branches

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[1] Loc. cit. p. 776.

of the ancient Bugaboo Creek; and from the ridge extending across the middle of the Sumner area it was separated by a branch of Crabapple Creek, and by the headwaters of the pre-glacial valley now occupied by Little Bonpas Creek, in the S. E. $\frac{1}{4}$, Sec. 21, and N. E. $\frac{1}{4}$, Sec. 28, T. 3 N., R. 13 W.

This ridge is more than 500 feet above sea level thruout its entire length and in many places its elevation exceeds 525 feet. At one point, in the S. E. $\frac{1}{4}$, S. E. $\frac{1}{4}$, Sec. 20, T. 3 N., R. 13 W., rock was found at an altitude of 551 feet, the thickness of the drift being only 9 feet. In general the thickness of the drift on the ridge varies from 10 to 25 feet.

South of this ridge, and on either side of its southern extension, the dominant feature of the pre-glacial topography is a large partially filled valley, with a branch valley of almost equal size, which are now occupied by Bonpas and Little Bonpas Creeks. There is also a smaller drift-filled rock valley occupied by Jordan Creek near the south border of the quadrangle. The latter is separated from Little Bonpas Creek valley by a rock divide which, just east of the center of Sec. 5, T. 1 N., R. 13 W., reaches an altitude of 550 feet, the drift being only 6 feet thick. The south side of this divide is quite steep, no rock being found in the well at the house one-fourth of a mile north of the southwest corner of Sec. 4 in the same township, at an elevation of 458 feet. The drift at this point is at least 20 feet thick. The elevation of the bottom of the old Jordan Creek valley is not definitely known, but in a well at the house one fourth of a mile north of the center of Sec. 18, T. 1 N., R. 13 W., rock was not reached at an altitude of 393 feet above the sea, the drift here being more than 28 feet thick.

As shown on the map of the pre-Pleistocene rock surface (plate III), the gradient of both the Bonpas and the Little Bonpas Rock valleys is quite gentle, especially in the lower part of their courses, altho the sides of the valleys are fairly steep. Good information is lacking concerning the lower ends of both valleys, since water is found some distance above the rock, not necessitating very deep wells. The greatest depth of the main valley is not known, but the rock lies less than 375 feet above sea level, as is shown in the absence of rock in a well in the N. W. $\frac{1}{4}$, S. E. $\frac{1}{4}$, Sec. 23, T. 1 N., R. 14 W., the bottom of which was at an altitude of 374 feet above the sea, the drift being at least 25 feet thick. Along Little Bonpas Creek, in the northwest corner of Sec. 29, T. 2 N., R. 13 W., no rock is reached at an elevation of 410 feet, the depth of the well being 14 feet.

In a well located in the main valley on a low hill in the S. W. $\frac{1}{4}$, Sec. 35, T. 2 N., R. 14 W., rock was found at an elevation of 393 feet. Rock was also found at an elevation of 402 feet near the middle of the N. W. $\frac{1}{4}$, Sec. 28, T. 2 N., R. 14 W., the thickness of the drift being 30 feet. No wells penetrate to rock on the flood-plain of any of the streams in this part of the quadrangle, the rock surface probably lying at least 25 or 30 feet below the surface of the flood-plain.

SUMMARY OF STUDY OF ROCK SURFACE.

The general nature of the pre-Pleistocene rock surface in different parts of the areas under consideration may be seen in the cross sections shown in plate IV, one across each quadrangle, which show both the present surface and the pre-glacial rock surface. These sections were chosen so as to show the most characteristic features. In plotting the sections the vertical scale has been exaggerated 33 times in comparison with the horizontal scale in order to show the small thickness of the drift found in some places. The vertical lines in the diagrams indicate the depth to rock in the wells, as located by numbers on the maps, and are placed at the proper relative distances from each other according to the scale.

With one or two exceptions which are easily explained, the sections reveal a close agreement between the present surface and that of the rock. Usually the rock lies within 30 feet of the surface. On the highest points, however, the thickness of the drift is often less than 10 feet. This is best seen in well No. 8, on the section AA in the Hardinville quadrangle, and well No. 6 on section BB in the Sumner quadrangle. On the other hand, the greatest thickness of drift is found in the deep valleys. This is the case in the oil wells on the flood-plain of the Embarass (wells No. 11 and No. 12, Section AA), and in the valley of Big Creek. However, it is not necessarily true that the depth to rock is always less on the smaller hills than in the valleys, nor that the thickness of the drift decreases propor-

SECTIONS SHOWING RELATIONS EXISTING BETWEEN THE PRESENT SURFACE AND THE PRE-PLEISTOCENE ROCK SURFACE

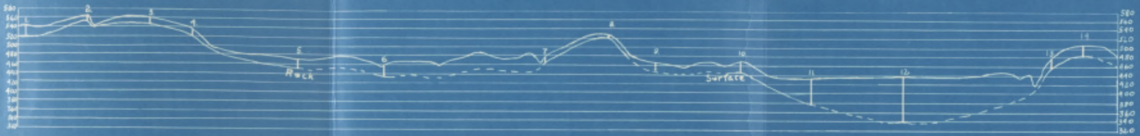

Fig. A — Section along line AA, Hardinville quadrangle.

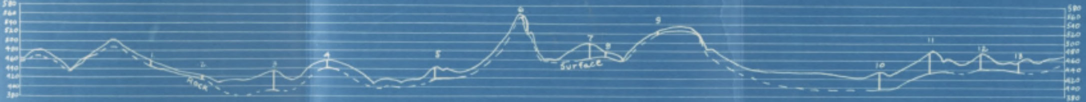

Fig. B — Section along line BB, Sumner quadrangle.

Horizontal scale

0 1 2 miles

tionally with increased height. This is illustrated in section BB where the surface at well No. 3 has a greater elevation than that at well No. 2, but the former well has a much greater thickness of drift, the rock surface being nearly 20 feet lower in well No. 3 than in well No. 2. The depth to the rock is also apparently greater than in the valley between the two wells, the lowest point in the section. However, since a well near the center of the N. E. $\frac{1}{4}$, Sec. 28, T. 2 N., R. 14 W., nearly two miles north of the line of the section, and located above the level of the flood-plain at an elevation of 432 feet, reached rock at an altitude of 402 feet, it is safe to assume that the rock surface in the valley between wells No. 2 and No. 3 lies at an altitude lower than 393 feet, which is the elevation of the rock at well No. 3. Another noticeable fact is that where the slopes are steepest the rock outcrops are the most frequent, the rock usually lying nearer the surface than in regions having a more gentle gradient.

Conditions Controlling the Relation between the Rock Surface and the Present Topography.

An appreciation of the close correspondence existing between the present surface and that of the rock requires a knowledge of the conditions under which the glacial drift was deposited, but no attempt will be made here to discuss the conditions and nature of glacial action[1]. It is to be noted, however, that the topography of this region differs markedly from that of the more recently glaciated areas farther north. In these areas which were covered with the latest or Wisconsin ice sheet, of which the Wheaton and Highwood, Ill. quadrangles are good examples, the topography is characterized by a lack of definite correlation between the land surface and the drainage lines, and the surface is quite rolling, with few hills as sharp as those found in the Hardinville-Sumner area. Many undrained, swampy depressions also occur over the uplands. In addition, there is usually no correspondence between the present topography and that of the pre-Pleistocene rock surface such as is seen to exist in the region under discussion.

Some of the reasons why the topography of the Hardinville-Sumner quadrangles does not show many of the usual characteristics of a region of extreme recent continental glaciation are the following:

The south boundary of the Sumner quadrangle is only about 35 miles north of the southern limit of the great drift sheet

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[1] For the benefit of the reader who desires a good knowledge of the Pleistocene period and the nature of the glacial drift, etc., the following references are given:

Salisbury, R. D., and others, The Glacial Geology of New Jersey, Vol. V., Geol. Survey of New Jersey, 1902, Part I. The Drift and the Glacial Period, for a general discussion of continental glaciation.

Leverett, Frank, The Illinois Glacial Lobe, U. S. Geol. Survey Mon. Vol. XXXVIII, 1899, for a detailed discussion of glaciation in Illinois.

which covers the greater part of Illinois.[1] As far as known, this entire area was covered only by the Illinoian glacier, no till of other glacial epochs being found in the region. The lower limit of the Illinoian drift in this part of the state is usually not marked by prominent terminal moraines, such as mark the line of lower limit of the later drift sheets. On the contrary, the drift apparently thins out gradually at the margins, altho some small ridges suggest the possibility of there once having been a moraine. If any terminal ridge was left by the ice, it has since been removed by erosion. The facts that the Hardinville-Sumner area lies near the southern limit of glaciation, and that it was covered by only one drift sheet, would account for the general thinness of the till.

It might be assumed that the drift was originally much thicker, and that much of the material was removed by erosion resulting in the present topography. This view would be supported by the fact that there have been at least two glacial epochs since the Illinoian, each of long duration, affording ample time for erosion to denude the drift and destroy the surface features existing at the end of the Illinoian stage. However, the field evidence does not sustain this ~~argument~~ view, for if the present surface is entirely due to erosion, why is there such a close agreement between the present topography and that of pre-

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[1] See Leverett, loc. cit. pl. VI, or the Patoka Folio, No. 105, U. S. Geol. Survey, the areal geology sheet.

Pleistocene time? If the configuration of the present land surface is due to the removal of large quantities of drift to form the valleys, the hills being caused by the uncovering of rock cores, we should expect to find much larger areas of rocks exposed. It is only along the streams that rock outcrops occur, and even there no very large areas are uncovered. It does not seem possible to account for the present hill and valley topography by erosion in a formerly level, deeply drift-covered area. If a great thickness of drift was deposited over the entire area by the Illinoian glacier, the surface would have been more nearly level after the retreat of the ice sheet than at present, the irregularities that then existed not being due to the underlying rock surface. In time, as the water from the melting ice drained off from the drift, the materials of the mantle of till would tend to shrink and settle, due both to their own weight, and to the loss of water. Examples of such settling are seen in tile ditches, etc., the filling of which in time settles down and leaves depressions. Since the amount of shrinkage would be greatest where the drift was the thickest, the deepest depressions due to settling would be above the pre-glacial stream channels. These depressions would determine the new lines of drainage which would tend to continue along these lines during subsequent Pleistocene and recent time, even tho unaffected directly by the rock surface. The difficulties in this view are:

First, the drift as deposited was probably in a somewhat compressed condition, due to the weight of the overlying ice, and hence there would be little settling. Second, it would seem probable that quite a thickness of drift would be necessary in order that the shrinkage or compression of the drift by settling would produce sufficiently large depressions to offset the post-glacial irregularities of the surface and determine the course of the drainage. It therefore seems probable that, altho settling and shrinkage would perhaps have some effect, it would influence the course of the drainage but slightly.

On the other hand, it does not seem that erosion has removed a very great thickness of the drift. The evidence against any great removal of till is found in exposures of loess, a fine silt which was deposited after the retreat of the Illinoian ice sheet. If the erosional denudation had been very great, these loess deposits which are not very thick would have been destroyed. On the contrary, the presence of the loess, both on the hills, and on the slopes at lower elevations points to only a comparatively small amount of general denudation of the surface since Illinoian time. That there has been so little removal of the drift may be due to the fact that the land surface during this period was very low in comparison to the distance from the ocean, and the consequent low gradient would prevent great erosion.

The most probable explanation of the close relation existing between the present topography and the rock surface seems to be that, since the margin of the ice sheet was but a comparatively short distance to the south, the ice sheet that covered this region was thin and its erosive power was week. As a result, the amount of drift brought by the glacier and left behind as it retreated was relatively small. In fact, it was not enough to obliterate the outlines of the large valleys, nor even of many of the smaller ones. It may have been that the surface of the ice was all at about the same level, and that it did not rise up in passing over the hills, but that it merely thinned out in these places. In this latter case, the amount of drift deposited would naturally be less on the hills, as shown by the diagram in figure 1. If, however, the drift was at first as thick

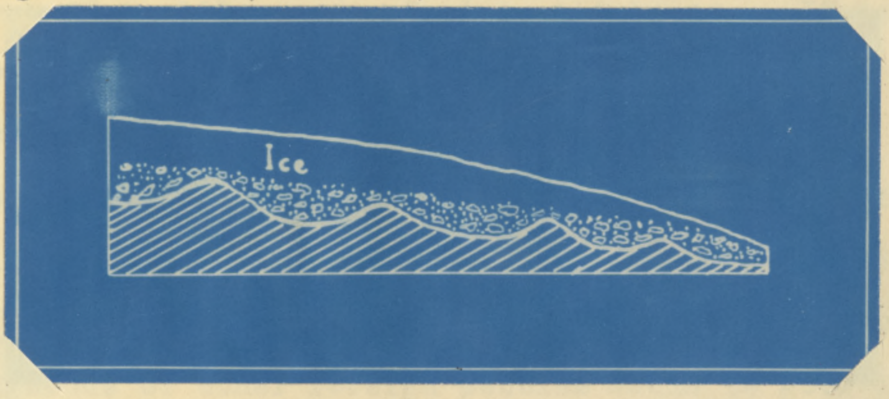

Figure 1.--Diagram showing how the greatest thicknesses of drift will accumulate in the valleys.

on the hills as in the valleys, in these places erosion would be greatest, tending to lessen the distance to the rock. In either case, it would also be expected that there would be less drift remaining on the steep slopes since in such places the loose material is very easily displaced by slumping and landslides, and more rapidly removed by sheet wash and stream erosion. The conditions of the latter theory do not involve ~~for~~ excessive erosion in the region since the retreat of the Illinoian ice sheet.

History of Embarass Valley.

The history of the present channel of the Embarass River and perhaps of those of some of the larger creeks is somewhat more complicated than that of the present surface as a whole. As indicated on the rock surface map (plate II) and in the section AA (plate IV), the rock valley of the Embarass River is quite deep, and is covered with a mantle of drift and alluvial material varying from 25 to 100 or more feet in thickness. It is not definitely known whether the glacier plucked and carried away all of the loose pre-Pleistocene river deposits, but it does not seem probable that it would do so except in the stream valleys that extended in the direction of the ice movement. The finding, below the drift, in any basin of gravel beds which did not contain any igneous or other foreign pebbles would be good indication of the presence of pre-Pleistocene stream deposits. Altho a number of the detailed logs from wells on the flood-plain of the Embarass and at other places were studied, no such evidence was found. However, it is quite possible that some ancient flood-plain deposits, lying on the lee side of steep slopes may have been covered and left undistrubed by the ice, in much the same manner as inter-glacial soil beds which were sheltered from the action of the ice erosion have been preserved in other regions. (See pp. 74, 80)

During the retreat of the Illinoian ice sheet the Embarass valley was probably occupied by a very large stream which was fed by enormous quantities of water from the melting ice front.

This great and unusual supply of water was probably furnished again during the Wisconsin stage of glaciation. Such a stream would have eroded quite a wide channel, and carried away much of the drift originally deposited in its valley. Evidence of such erosion is seen in the sharp, almost vertical contact between the till and alluvial materials in exposures near the edge of the flood-plain. But later, as the ice front retreated farther and farther northward, the supply of water became less, and the stream began to deposit its burden. Deposition has since been going on in great or small quantities for a very long period. At present the river usually overflows the banks of its narrow channel at least once a year, and as the water spreads out over the

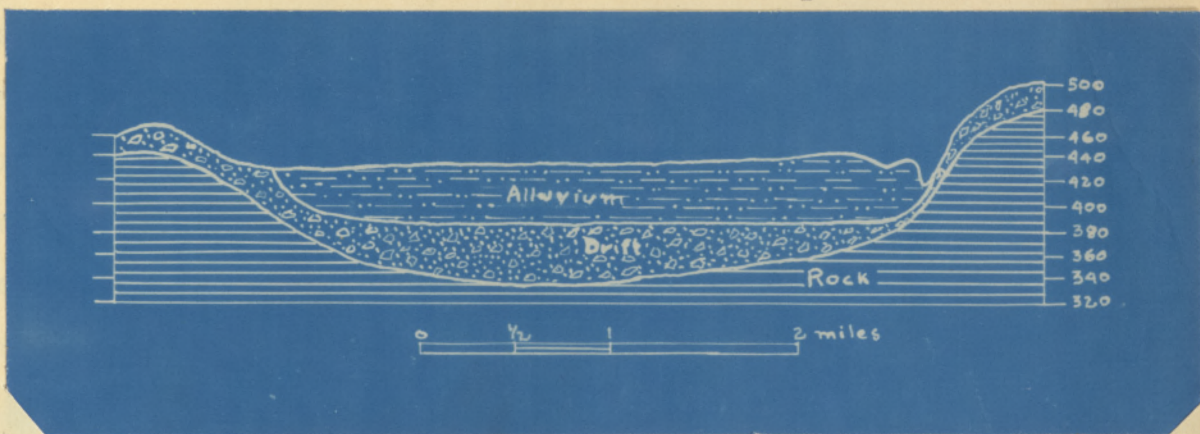

Figure 2.--Section showing probable relations existing between the rock , drift, and alluvium of the valley of the Embarass River.

flood-plain the current is slackened, resulting in the deposition of more material. During all this time the river has been meandering over its flood-plain. The result of this process of aggradation is a considerable thickness of alluvial material. In a number of places exposures in ditches dug on the flood-plain show the materials of the valley bottom to be sand and gravel and river silt. A few miles east of Chauncey wells have been driven on the bottom land as much as 40 feet into the sand and gravel beds before encountering clay of such a compact nature as to prevent the further sinking of the pipe. The clay below these beds is solid and stiff, and is probably drift clay. The entire thickness of the beds thru which these wells are driven is probably a flood-plain stream deposit, laid down since Illinoian time. If this be the case, then it is evident that a very great thickness of the material in the large valley of the Embarass has been built up since the melting of the ice sheet, but the exact periods during which the erosion of the drift and the later deposition of such a great amount of alluvium occurred cannot be definitely ascertained. However, it seems quite probable that the greater part of the process of alluviation had been accomplished by the end of the Wisconsin epoch of Pleistocene time. The probable relations existing between the rock, drift, and alluvium of the Embarass valley are shown in figure 2.

The explanation of the formation of the great flood-plain of the Embarass river probably holds true for the history of the flats of the other broad valleys of the area. In the other regions, however, detailed information is lacking. A well at the house just east of the center of Sec. 23, T. 1 N., R. 14 W., on the flood-plain of Bonpas Creek, was dug thru a bed of black dirt 7 feet thick, the bottom of which was 20 feet below the surface. At a depth of about 18 feet, a four inch layer of sand containing mussel shells was found in this black bed, indicating that at least the upper 20 feet of material at this place is of alluvial origin. Aside from this record there is no other definite evidence, elsewhere in the region, as to the fluviatile origin of a considerable thickness of the material of the flood-plains of the streams.

From the evidences at hand it seems probable that there have been no great changes in the drainage from that existing in pre-Pleistocene time. Aside from the filling of the valleys of the Embarass and of other streams the only important difference between the present drainage and the former drainage is found in the valley of Big Creek. Here we now find three streams where before only a single large one existed, as indicated on the map showing the pre-glacial rock surface.

This change is due to the filling of the large valley by glacial drift, and not due to filling by post-glacial alluviation, for as shown in the discussion of the Pleistocene materials on a later page (p.73) there are practically no flood-plain deposits found in this part of the area.

The effect of glaciation on the entire region was to lessen the relief of the land. This was affected by the planing down of the eminences and filling up of the valleys. Whereas the greatest relief of the pre-glacial rocks surface in the area probably was more than 250 feet, the present relief is not above 200 feet.

UNDERGROUND WATERS.

SOURCE AND OCCURRENCE.

Precipitation.

The source of practically all underground water is rainfall. The average rainfall of the Hardinville-Sumner area is approximately 40 inches. For the year 1912, however, it was about 3 inches above normal.[1] Altho it is the general conception that all underground waters have their origin in rainfall, Fuller[2] states that there are other possible sources for such water, but the effect of these other agencies is so small in the area under consideration that they will not be discussed in this report.

DISPOSAL OF RAINFALL.--The rainfall is disposed of in three principal ways. Evaporation is quite important in this process of removal. Some of the rainfall is also carried away by surface run-off, the water eventually reaching large bodies of water. The remainder of the rainfall is absorbed or enters into combination with the soil or rocks.

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[1] Annual Summary, 1912, Illinois Section of the climatological service of the Weather Bureau, map on p. 12, showing annual precipitation, and reports on p. 9 from stations at Palestine and Albion, the weather bureau offices nearest the Hardinville-Sumner area.

[2] Fuller, M. L., Underground Waters of Eastern United States: Water-Supply and Irrigation Paper No. 114, U. S. Geol. Survey, 1905, p. 18.

The approximate proportions of the rainfall which is disposed of by each of these three agencies, evaporation, run-off, and absorption, will vary in different regions. Fuller[1] states that the amount evaporated "commonly amounts to one-half or more of the total water falling as rain," and he places the proportion of run-off to rainfall in different parts of the Mississippi basin between 15 and 90 per cent. This would leave but a small amount to be absorbed by the soil and rocks. The statements of Bowman,[2] however, do not agree with these figures. In fact, the latter apparently contradicts himself, for he says, "The greater part of the precipitation on most areas is disposed of directly by run-off through surface streams," but in the same paragraph he states that "In the eastern half of the country the run-off will probably not average more than 20 per cent of the rainfall. In the West, although the percentage of run-off in small areas is at times great, it is on the whole less than in the East." A few lines below he makes the assertion that "The ground receives the greater part of the rainfall, probably nearly 80 per cent in the eastern United States and 90 and 95 per cent in much of the West." The author has not been able to

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[1] Loc. cit. p. 20.

[2] Bowman, Isaiah, Well drilling methods: Water-Supply Paper No. 57, U. S. Geol. Survey, 1911, pp. 10 and 11.

find any definite figures which throw any light on the apparent discrepancies of these two writers.[1]

It may be said that in the area under consideration, a rather large amount of the rain, including much of that which has sunk into the ground, reaches the streams within a few hours after it has fallen. This is probably truer now than it was a few years ago, and is due to the fact that so much farm and swamp land has been drained by tile thru which a great deal of the water absorbed by the earth quickly runs off to the streams. Many of the river floods of recent years have been attributed to the fact that the tiling and deforestation of the land has caused an immense amount of run-off to reach the rivers in a few hours after a storm, taxing the capacity of the streams. In past years, before so much tile had been laid, the water often took days instead of hours to percolate thru the soil and reach the streams, so that the time of run-off was stretched over a longer period, and the streams were able to take care of the great volumes of water.

The Water-Table.

When rain water sinks into the ground it will eventually reach a depth where the soil and rocks are saturated with water. The upper surface of this zone of saturation is called the ground-water level or the water-table, and the water which is in the soils or rocks below this level is commonly called ground-

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[1] U. S. Geological Survey Water-Supply and Irrigation Paper, No. 80, the relation of rainfall to run-off, by George W. Rafter, deals with this subject, but no statement was found assigning definite proportions to the three agencies. In this bulletin only evaporation and run-off were considered, since the ground water eventually is disposed of by one or the other of the two methods.

water. The water-table is not perfectly level as is the surface of the water of a lake or pond, but it is highly irregular. Permanent streams or swamps are found where the zone of saturation reaches to the surface, but usually this water-level is some distance below the top of the ground.

VARIATION IN HEIGHTH OF WATER-TABLE.--The depth to the water-table varies, and is dependent on a number of factors. The amount of precipitation in a region probably has the greatest influence on the height of the ground-water level, it lying much deeper below the surface in arid regions than in more humid areas. Variation in the amount of rainfall also effects the heighth of the water-table. The underground water is continually moving toward permanent streams, at a rate varying largely with the nature of the soil or rocks. During long periods of drought the water flowing toward the streams is not replaced by rain water, and naturally the supply of underground water will diminish, and the ground-water level will be lowered. This may continue until the temporary streams become dry. Variation in precipitation, with consequent effect on the water-table, has an important bearing

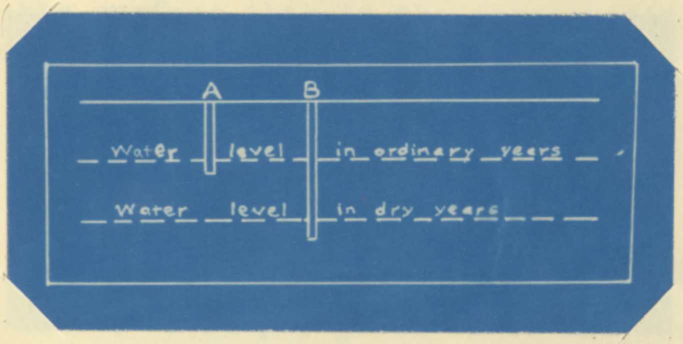

Figure 3.--Diagram showing relation between depth and permanence of wells.--A, Well sunk to ordinary water level, but failing at times of drought; B, well sunk to level of water in dry years, and hence never failing. (After Fuller)

on the water supply in regions where the population is largely dependent on shallow dug wells, as is shown in figure 3. In order to yield a permanent water supply a well must be dug below the surface of the water-table in dry years.

The depth to the ground-water level is also dependent on the nature of the rock or soil. Rocks and soil of a very fine-grained, closely compacted material afford comparatively little pore-space for the water, and hence furnish less favorable conditions for water to percolate or move thru them toward the streams than do the coarser soils and rocks. In such impervious materials the level of the water-table is usually nearer the surface than in the more porous beds, such as sand, gravel, or sandstone. Among other factors affecting the height of the ground-water level are evaporation, temperature, and atmospheric pressure.[1]

In addition to periodic variations of the ground-water level, in many regions there has been a permanent lowering of the height of the water-table, as shown by data collected by W. J. McGee.[2] He shows (p. 161) that in Illinois out of a total of

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[1] Van Hise, C. R., A treatise on metamorphism: Mon. Vol. XLVII, U. S. Geol. Survey, 1904, pp. 423-429. Veatch, A. C., Fluctuations of the water level in wells, with special reference to Long Island, New York: Water-Supply and Irrigation Paper No. 155, U. S. Geol. Survey, 1906. Part II of this paper is devoted to a detailed discussion of the fluctuation of the water in wells, with a very complete bibliography on the subject.

[2] McGee, W. J., Wells and subsoil water: Bull. 92, Bureau of Soils, U. S. Dept. Agr., 1913, pp. 49-53, 161.

710 shallow wells reported, 443 or 61 per cent showed a change in the water level in a number of years between the time the well was first dug and the time when the report was made. Of this 61 per cent showing a change in height of the water-table, in 401 or approximately 90 per cent, the water level is now an average of 5.12 feet lower than when the well was first dug, making the fall per decade about 0.879 feet. In a number of localities it was reported that many old shallow wells had become completely dry. The change is less notable in the deep wells. This change in the height of the water-table, which is found to have occurred in many parts of the United States, is attributed to a number of causes, among which are increased run-off due to deforestation and tile drainage, excessive draft on wells in certain districts, unnecessary waste of water, and the increased consumption by man and animals with increased population.[1] Some of these causes are more active in certain regions than in others. Mr. McGee's work serves to point out the gravity of the problem of the conservation of our underground water supply, and the need for legislative action to prevent the unnecessary waste of this resource which is of so great importance to mankind.

Configuration of Water-table.

As noted above, the surface of the ground-water level is very irregular. Its configuration is influenced by a number of factors. Gravity tends to cause the water to assume a uni-

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[1] Ibid, pp. 179 ff.

form level, but opposed to this force capillary attraction, which acts between the water particles and the grains of materials in which the water is found, tends to prevent the water from reaching a horizontal plane. This capillarity is greatest in the fine grained, impervious beds, such as clay and shale. Hence, in fine-grained soils or rocks the level of ground water will be more irregular than in regions of more porous sand and gravel

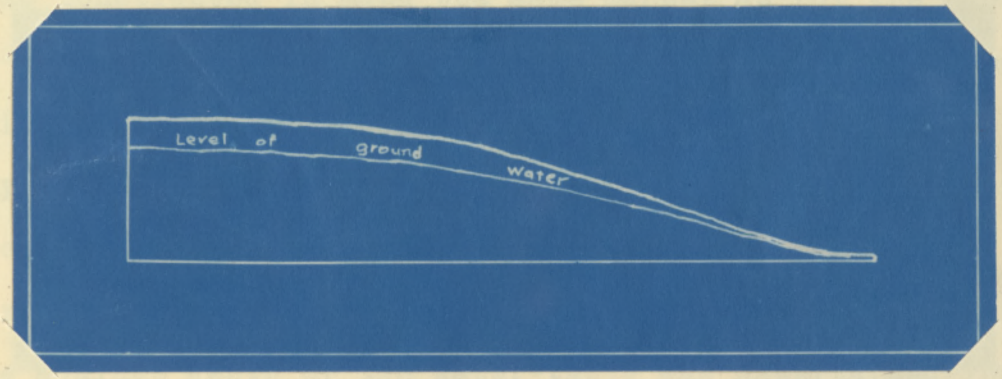

Figure 4.--Diagram showing difference between the gradient of the water table and that of the surface.

beds or sandstones. Usually the water-table has much the same configuration as the land surface, altho there are some exceptions. For instance, on hill sides the ground-water level commonly has a gentler gradient than the surface, and the depth to water is usually less in the valleys than on the hill sides or on the tops of the hills. This is illustrated in figure 4. The water level is also frequently found nearer the surface at the tops of hills composed of clay than in similar locations where the soil is sandy.

WATER-TABLE OF HARDINVILLE AND SUMNER QUADRANGLES.--In connection with the study of other problems of the water resources, information was collected concerning the ground-water level in the Hardinville-Sumner area. The depth to the water was measured in practically all of the wells visited. The elevations of the water level thus obtained were plotted on topographic maps of the quadrangles, and a contour map of the ground-water level was constructed in much the same manner as for the maps of the pre-glacial rock surface. These maps showed that the configuration of the water-table corresponded so closely to the topography of the present surface that it was not thought desirable to present them in this paper, altho there were a few minor departures from the contours of the present surface.

The average depth of the water-table was ascertained for the different types of topography in the quadrangle. On the comparatively level prairie lands of the Hardinville quadrangle, the average distance to the water-level was found to be about 7 feet. For the upland prairie in the vicinity of Claremont, on the Sumner quadrangle, the average depth was about 9 feet. In the more dissected parts of the Hardinville quadrangle the average depth was about 13 feet, while for the more rugged parts of the Sumner quadrangle it was almost 17 feet. The average depth of the water-table in the valley bottoms of the Hardinville quadrangle was about 7½ feet, and for the similar regions in the Sumner quadrangle about 8 feet. The average for the lowlands would probably be less if more data was obtainable on the flood-plain of the Embarass, but most of the wells in this region are driven, and hence the depth to water could not be measured. It is noteworthy that the average for each type of topography is lower in the Hardinville quadrangle than in the Sumner quadrangle. This is probably due to the fact that in the latter region a much larger per cent of the wells are dug in the drift or rock, and do not penetrate sand or gravel beds.

The mean depth of the ground-water level for the whole area is about 12 feet below the surface. Probably the depth to water in 75 per cent of the wells does not differ more than five feet from this average. There were, however, some radical departures from these figures, in some cases the water standing within a few inches of the surface, while in two or three cases it was more than 40 feet to the water level. Nevertheless, in most of the wells (by an actual count more than 90 per cent), the depth to water was less than 20 feet, the mean variation being about 8 feet from the normal. Thus, in making a contour map of the water-table it was found that the contours of the water-level seldom crossed the surface contours. For instance, on the map the 450 ground-water contour is usually shown to pass thru places with an elevation a little above the 460 surface contour, the 475 water contour at places not quite half way between the 480 and 500 foot surface contour, and the 500 water contour at places a little more than half way between the 500 and 520 surface contour. Therefore the depth to water at places between any two surface contours could usually vary from 8 to 10 feet one way or the other without the water contour crossing a surface contour on the map. However, the 450, 520, and 550 foot water contours would quite likely cross the 460, 540, and 560 surface contours, respectively, since they were usually located at places having an elevation so near to the respective surface contours, that only a slight variation in the depth to the water-table would be required to cause the water contour to cross the surface contour. It was found in a number of cases that the water-table contour, instead of following a surface contour which represented a narrow projecting arm of a ridge, would cut across such an extension.

The variation in the water-level in the wells seemed to be due to a number of causes. The greater number of wells in which the water-level was excessively low were found among those dug into the rock. In such cases it is quite likely that the drift above the rock was saturated, and that if the well had not been dug into the rock the water level would not have been so low. But in such cases, when the rock was penetrated the water which seeped in from the drift flowed away, either thru crevices in the rock, or thru the rock itself if it was quite porous. This would be especially likely to happen if the well was situated on a hill side, if the porous bed was prevented from receiving any surface water by an overlying impervious bed. The effects of joints and fissures in the rock is illustrated by a well located in the oil fields. The well is dug into the rock 36 feet deep. The water formerly stood much higher than at present.

A few years ago, in drilling a water well for an oil pumping station a few hundred feet distant, an extra heavy charge of nitroglycerin was exploded in the bottom of the drill hole to shatter the rock and make a collecting basin for the water. The surrounding rock was fissured for some distance, and the water in the dug well was drained away until it is now only 4 or 5 feet deep.

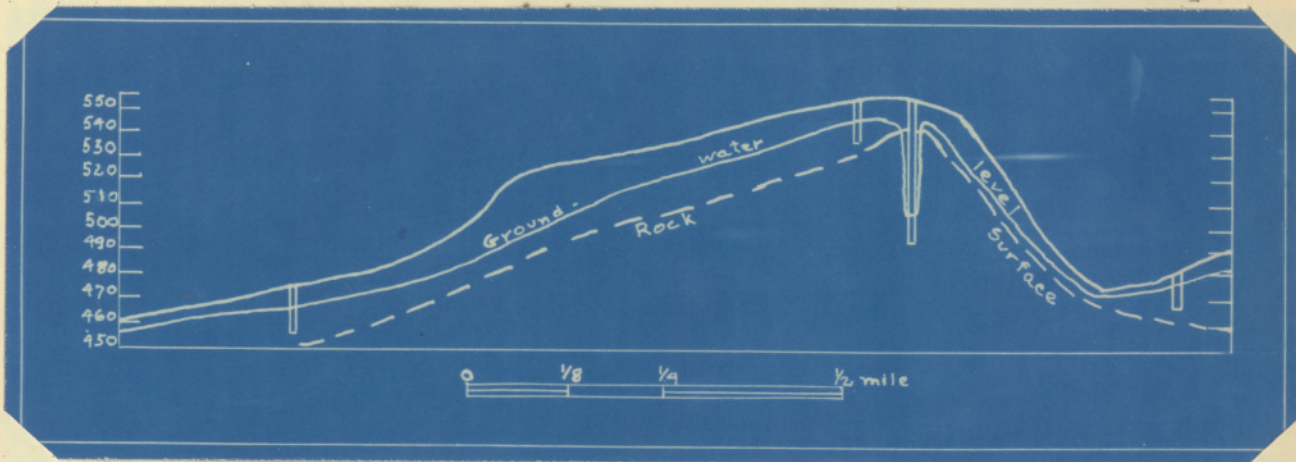

Figure 5.--Diagram showing difference between level of water in a well dug in rock, and in one dug in glacial drift.

An excellent example of the difference between the water level in wells dug in the rock and those dug in the drift is found in two wells at the house on the summit of a large hill in the S. E. $\frac{1}{4}$, Sec. 15, T. 2 N., R. 13 W., where one well was dug 61 feet deep, rock being reached at 12 feet from the surface, and the depth to water being 49 feet. A second well about 200 feet west of the house, on ground one foot higher than the first did not reach rock at 18 feet, and the depth to the water was only 8 feet. In this case the surface water near the deep well had been drained by the porous or jointed rock. The probable shape of the water-table at this place is shown in figure 5.

Another case where the depth to the water in the well was unusually great was at the house on the summit of a high hill in the S. E. $\frac{1}{4}$, Sec. 34, T. 4 N., R. 13 W., where the water level was 36 feet below the surface. In this well it was said that the water comes from quicksand at the bottom. The great depth to the water might be explained by the sand draining off the greater part of any water which might seep in from the overlying beds of till. It was frequently found that on hills of

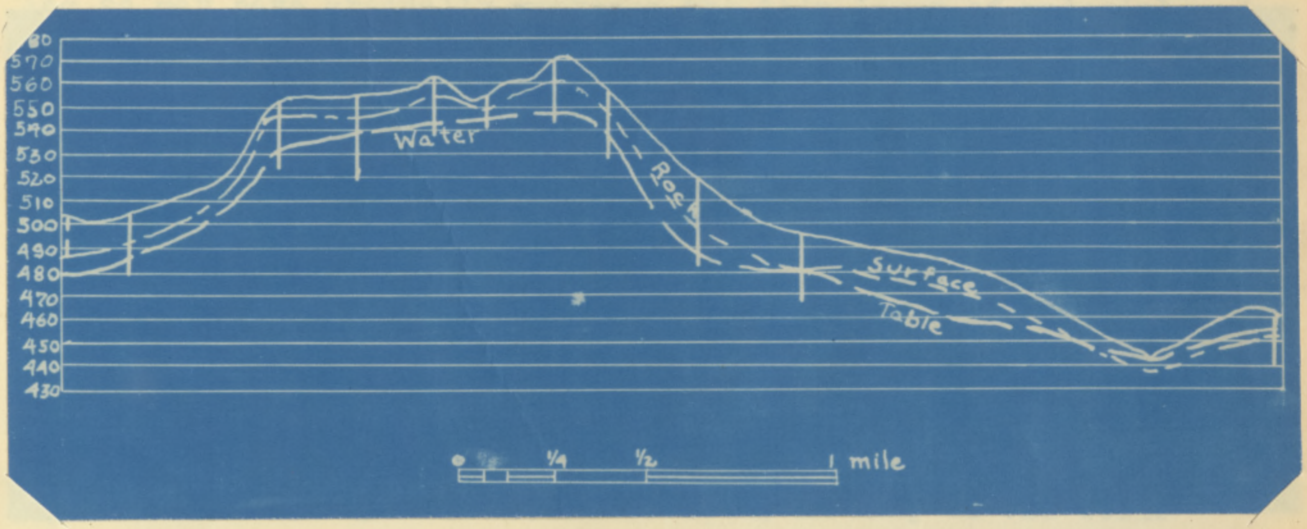

Figure 6.--Section along line CC, showing the relation between the drift surface, water-table, and rock-surface.

very sandy material, the water-level was rather low since such porous materials readily permitted the water to drain off to lower land.

Figure 6 shows the outline of the water-table along the line CC, a little south of the center of the Sumner quadrangle.

One or two wells were found in which, soon after they were dug, the water level was easily lowered by pumping, and the supply was insufficient in dry years, but a few years later the water came in abundantly and has continued to do so. In one case the owner of the well said that the water supply was increased after an earthquake a few years ago. In such wells it is probable that when the well was dug a good water-bearing bed was not reached, but the bottom of the well was quite likely only a short distance above such a bed. The water probably at one time or another percolated upward into the well, and in doing so may have gradually weakened the thin layer of material above the porous sand or gravel bed, and finally broke thru it to the bottom of the well.

Probably other conditions enter as factors which cause the abnormal depth to water in some of the wells, but they will not be considered at this time. The summer of 1912, during which the well records were collected in the Hardinville-Sumner area, was one of abundant rainfall. In periods of drought, it is therefore likely that the water level in many of the wells would be much lower when they were measured. In fact many people reported that their wells are completely dry in periods of extended drought.

WATER-BEARING STRATA.

All rocks and soils contain more or less water. Many of them, however, do not hold it in appreciable amounts, nor do they part with it readily, and hence are not suitable for furnishing it in quantities sufficient for a permanent water supply. The usefulness of a rock as a water-bearing stratum depends upon its porosity. The porosity of a rock is in turn dependent on the fineness of its component materials, for the coarser these materials are, the less closely do the grains interlock, and the larger are the pores that contain water. Accordingly, sand and gravel, and coarse sandstones are the best water-bearing beds. Fuller[1] states that the pore space of some sand and gravel deposits is as high as 30 per cent of the total volume. This great porosity of the beds permits ready circulation of the underground water, so that as water is drawn out of wells, it more quickly flows in again. On the other hand, clays and shale, which usually are saturated with water, have such small pore spaces that the movement of the water thru such material is very slow, being greatly retarded by the increased capillary attraction existing between the numerous fine mineral grains and the water. Hence, when water is pumped from a well dug in clay or shale, the water level is quickly lowered, and the water seeps in again only very slowly. However, wells dug in clay or shale frequently furnish an adequate supply, when the water can flow in thru joints or cleavage cracks. Limestone is another rather impervious rock, not generally yielding large quantities of water, but frequently the limestone is jointed, and the joints are enlarged by solution, leaving solution cavities, thru which the

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[1] Loc. cit. p. 11.

water may circulate freely, affording an abundant supply. In fact, the most of the wonderful underground streams and caverns found in many regions follow large solution channels in limestone rock.

The wells of the Hardinville and Sumner quadrangles receive their water supply from all of the different kinds of beds named above. The majority of the wells are dependent on the unconsolidated glacial drift and Recent alluvial deposits for their supply. The Pleistocene deposits may be divided into two classes: 1) sand and gravel beds, and 2) the unassorted till, or boulder clay which constitutes the greater part of the deposits. An abundant supply of water is usually found in beds of sand and gravel, but the clay is a poor water-bearing formation. Of the wells which are dug into rock the best ones receive their supply from sandstone formations. A few wells derive the water from shale or limestone, but in such cases the amount is usually limited as in the case of the wells dug in the glacial clay. The wells of this region obtaining water from sand and gravel, till, and rock, respectively, are indicated by different symbols on the maps, plates II and III.

REGIONAL DISTRIBUTION OF WATER-BEARING STRATA.

Hardinville Quadrangle

The distribution of the various water-bearing strata in the region is somewhat discontinuous. Nearly all of the wells in that part of the area north of the Embarass River are supplied from Pleistocene beds of sand or gravel. A few, however, find the water either in unassorted glacial till, or in rock.

There are two areas in which the water is obtained from the rock. The first of these is on the ridge which extends southwest from the northeast corner of the quadrangle almost to the Embarass River southwest of Hardinville. On referring to the map of the pre-glacial rock surface (plate II), it is seen that this ridge is underlain by a rock core that rises to within 25 or 30 feet of the surface. The other area in which the water is often secured from the rock is in the highland region in Honey Creek township, northeast of the Embarass, and extending south into Bond township as far as Westport. A number of the wells in the less elevated part of this latter region are supplied from beds of sand or gravel. In both of the areas above mentioned the rock which furnishes the water is sandstone. It is not known whether the water comes from a single bed of sandstone of considerable thickness, or whether the rock reported in the different localities represents a number of different beds separated by strata of shale or limestone. The sandstone beds, however, are quite thick, for a ledge of sand rock, 19 feet high, outcrops along the stream near the center of Sec. 17, T. 6 N., R. 12 W., from the water level up to an elevation of 497 feet, and a thickness of 37 feet of sandstone was reported in a well at the house on the summit of a hill in the S. ½, Sec. 3, T. 5 N., R. 12 W., the elevation of the top of the sandstone at this place being about 584 feet. It is not likely that the sandstone in these two places is a part of the same bed, but it seems quite probable that the rock found in the wells at the lower levels is a part of a single formation.

As was mentioned above, the greater number of the wells north of the Embarass are supplied by sand or gravel beds in the glacial drift. The depth of the water-bearing beds below the surface varies, but it is usually from 10 to 20 feet. In many places the glacial till has become consolidated by a cement of calcium carbonate precipitated from solution in percolating waters forming what is known locally as "cement rock" or simply "cement". The cement rock is very impervious, and so does not furnish a good water supply. In some cases it was found that a sand or gravel bed occurred between two layers of cement rock, in one well 7 feet of cement being reported above the water-bearing stratum and 20 feet of cement below it. However, it could not be ascertained whether this was always the case, for frequently when a good water-bearing sand or gravel bed was reached the well was dug no deeper, so that neither the thickness of the water-bearing stratum nor the nature of the underlying formations was determined. In one or two places a sand or gravel bed was found between the unconsolidated drift and the more indurated phase of the drift rock.

It has not always been possible to determine whether the sand and gravel found in a number of neighboring wells were continuous beds. In most cases in the wells on the high elevations the water-bearing beds are found at correspondingly higher elevations than in the wells on the lowlands. This might be interpreted as indicating that the sand and gravel was a continuous layer, sloping away from the hills in all directions.

However, the information from a few wells showed that at least some of the sand beds were more in the nature of narrow streaks in the drift which did not extend entirely across the well. Also, in some wells more than one sandy vein was reported.

The origin of the sand and gravel beds located within the drift may be explained by assuming that they were laid down by streams flowing under the ice, and the sorted stream deposit was later covered by the unassorted till when the ice melted. Another possible explanation is that the sand and gravel beds were outwash materials deposited in front of the ice margin during a temporary retreat of the glacier on drift left after the first advance, and that they were later covered by till when the ice sheet again advanced. No certain evidence was found that a bed of sand and gravel occurs immediately above the rock, altho some of those the bottom of which was not reached, may lie at the very base of the drift.

There is no evidence that any of these water-bearing sand beds were laid down as flood-plain deposits in post-glacial time except on the flood-plain of the Embarass River. In nearly every well the water-bearing beds lay beneath pebbly clay (till) or the more indurated cement-rock phase of the drift. Probably in a very small area on the low valley flats, and confined to a narrow strip on each side of the streams they occur beneath alluvial material.

At most of the houses in the region along the west side of the quadrangle, in Sainte Marie township, within one-half mile of the flood-plain of the Embarass, or the North Fork of the Embarass, no till or cement is found in the upper part of the wells, but the first material penetrated is sand, below which is often found a black, sticky mud. In a few places considerable wood was reported in this muck. At the house in the southeast corner of the S. W. $\frac{1}{4}$, Sec. 28, T. 6 N., R. 14 W., such a bed of muck, containing many wood fragments was reported 9 feet thick. Where the wells passed thru these beds of sand and muck or peat, till or cement rock was always found below them. In one well a layer of sand occurred both above and below the muck. The evidence points to the post-glacial origin of the muck, and it is probably a marsh or local flood-plain deposit. The sand beds lying above the drift are probably dune deposits, for the soil in this region is sandy, and the topography is similar to that found in typical sand dune areas.

Muck containing leaves and twigs was also reported in a well at the house north of the road in the N. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$, Sec. 25, T. 6 N., R. 13 W. At this place, however, the muck lay at a depth of 45 feet, below a thickness of 33 feet of cement rock. This well is now filled up, so that the depth of the well could not be verified. The explanation of this lower muck layer, below drift, is that it is a remnant of the pre-Illinoian soil zone which was in such a position that it was protected from erosion by the Illinoian ice sheet.

The water supply of a few wells in the north half of the quadrangle are supplied only by seepage from the till, and frequently fails in dry periods. In such cases either the well was not dug deep enough to strike a water-bearing layer, or no such porous layer was present in the drift at those places. Occasionally wells in the drift receive an abundant supply of water thru crevices in the cement rock.

The underground water conditions are quite different in the southern half of the Hardinville quadrangle from those in the north part. Nearly the entire flood-plain of the Embarass River is underlain by a considerable thickness of alluvium, composed of alternating beds of sand, gravel, and river silt which is very loose. A large number of the wells on the flood-plain are of the driven type, a pump-point being easily sunk thru the alluvium until it reaches a gravel bed. The depth of the driven wells usually varies from 15 to 35 feet; rarely one is driven deeper. At most places on the flood-plain water-bearing beds are reached within 20 feet of the surface, but the pipes are usually sunk deeper in order to secure a water supply that is safe from a sanitary standpoint, and to reach beds of a sufficient gravelly nature that no trouble will result from loose sand clogging up the pump points. The driven wells furnish abundant supplies of water. Only a very few wells are dug in this part of the area, and these usually reach water beds at depths less than 15 feet, and the water usually stands within 10 feet of the surface.

Besides those wells on the flood-plain of the Embarass very few in the south half of the Hardinville quadrangle are supplied by gravel beds. Practically all such beds are confined to the valleys of the small streams, altho sand and gravel beds were reported in three or four wells at the foot of the slopes on both sides of the north half of the highland near the west side of the quadrangle. In one place the water-bearing bed was just above rock, but no information was obtainable on this point at the other wells. All of the sand and gravel beds in this part of the area seem to lie within the drift.

Over a small area in Southwest township, reaching from Landes north and west to the river, conditions are much the same as along the river in Sainte Marie township. In this region the upper material is sand, in places nearly 20 feet thick. This is apparently another area of sand dune formation. In two places muck was found below the sand.

Practically all of the wells in areas other than those just mentioned, are supplied from the rock, only a few being seep wells in the drift. This applies not only to the upland regions, but also to the elongated trough which lies in the western half of the quandrangle, extending from the Embarass to the south boundary of the Hardinville quadrangle. Many of these wells in rock are entirely drilled, or else are dug part way and drilled deeper. In some cases the drilled wells are more than 200 feet deep, while others find a good supply of water at less than 100 feet. The water supply in the rock wells usually comes from sandstone.

Sumner Quadrangle.

A much smaller number of wells in the Sumner quadrangle are supplied from sand or gravel beds than in the Hardinville quadrangle. Practically all of these are located in the valleys.

Very uniform conditions are found in the vicinity of Sumner. Well diggers at this place state that most of the wells in the town strike a bed of quicksand, 1 to 10 feet thick, at a depth between 10 and 15 feet. Usually this quicksand is overlain by a layer of cemented gravel or drift about 6 inches thick, which is in turn covered by a 2 to 4-foot bed of red sand. Above the red sand is clay. Some wells are dug only to the red sand and fail in dry seasons, but the lower sand bed furnishes a permanent water supply.

The possible origin of the sand and gravel beds at this place is as follows: When the ice front stood only a few miles north of the site of Sumner, either during its advance or retreat, it dammed up the valley now occupied by Muddy Creek, and a small lake was thus formed in front of the glacier. In this lake the sand and gravel beds were deposited. If this lake was formed during the advance of the ice, the lake beds were probably not much disturbed as the glacier later moved over them. Since the retreat of the ice these beds have probably been covered with a thin layer of alluvial material.

In the valley near Bridgeport the wells also penetrate sand and gravel beds. In the town of Bridgeport a number of wells are drilled in rock, and are used largely by the oil well operators. Only a very few wells are supplied by sand or gravel beds in Raccoon Creek valley, and only two were reported in the valley of Crawfish Creek, altho it is likely that some which were not visited reach such beds.

Concerning the origin of the sand and gravel beds found in the valleys of Raccoon and Crawfish Creeks there is no definite information. The finding of beds of muck with wood and other vegetable matter in some of the wells points to a possible marsh or flood-plain origin. In a well at the house in the northwest corner, N. E. $\frac{1}{4}$, Sec. 7, T. 1 N., R. 12 W., quicksand was found at a depth of 18 feet, and at about 30 feet there was reached a 3 foot layer of bluish sand with much decayed vegetation. The owner said this mucky layer looked like a decayed brush heap. Below this was pebbly clay to 40 feet, to the bottom of the well, which was on soft sandstone. In a well dug at the house in the southwest corner of the N. W. $\frac{1}{4}$, Sec. 7, T. 1 N., R. 12 W., the owner said the upper 12 feet appeared to have been filled in, below which was 7 feet of red clay above a shelly sandstone. The red clay may be oxidized till of Illinoian age.

Muck, with wood fragments, was also found at a depth of 33 feet in a well near the west side of the W. $\frac{1}{2}$, S. E. $\frac{1}{4}$, Sec. 30, T. 2 N., R. 12 W., and also between the depths of 18 and 33 feet in another well in the southeast corner of Sec. 24, T. 2 N., R. 13 W. In both cases the muck was underlain by clay, and in the last mentioned well the clay was pebbly. No definite information could be obtained concerning the nature of the materials in the upper part of the well, but the evidence seems to show that these beds of muck are post-Illinoian swamp accumulations.

Probably the greatest number of wells in the Sumner quadrangle in which sand and gravel are found are in the valleys of of Bonpas, Little Bonpas, and Jordan Creeks. In the first named valley such water-bearing horizons occur scattered as far north as Claremont, in Little Bonpas valley nearly as far as the north line of Lukin township, and in the valley of Jordan Creek well up to the base of the ridge which crosses the quadrangle in a north and south direction.

With one or two exceptions noted below, all of the sand and gravel layers found in wells in the valleys of Bonpas, Little Bonpas, and Jordan Creeks seem to be stream deposits within the drift, for in every case where the information was definite the beds are overlain by till. In one well, near the center of Sec. 23, T. 1 N., R. 14 W., a white soil was found reaching to a depth of 13 feet, below which was 7 feet of black soil having no wood fragments, but containing a 4 inch layer of sand about 2 feet from the bottom in which were clam shells. Another well about 500 feet east of the last did not penetrate any black dirt. It was reported that in the lower 12 feet of the well at the house north of the center of Sec. 18, T. 1 N., R. 13 W., the north side was in sand, while the south side was blue clay. These records indicate that at least a part of the flood-plain of the creek is alluvial material. It seems probable that the last mentioned well was dug at the contact between the flood-plain material and the drift. It is very probable that the area which has been filled in by alluvium since the retreat of the glacier is confined to a comparatively narrow belt bordering the larger stream channels.

In the west half of the quadrangle a bed of muck was found at a number of places. A layer of peat about one foot thick outcrops in the road near the center of Sec. 17, T. 2 N., R. 14 W. It is overlain by yellow clay, while below it is a blue clay thot to be weathered shale, for a bed of shale is exposed five feet lower in the hill. Coal was said to have been found in a well on the south side of the road at the house about one-eighth of a mile farther west, and it was also reported that coal outcropped in the nearby ravines. It seems probable that this so-called coal is a bed of peat, probably a continuation of the one exposed along the road. This bed has a similar relation as the bed of peat found in the Patoka quadrangle south of the Sumner[1], underlying the Illinoian drift, and hence is probably of pre-Illinoian age.

Muck containing wood fragments is also reported in two wells in the N. W. $\frac{1}{4}$, Sec. 25, T. 2 N., R. 14 W., and is said to be exposed in a near-by field. A sand bed was reported below the muck, and under the sand was pebbly clay. A three foot layer of muck above pebbly clay was found at a depth of 20 feet in a well in the extreme southeast corner of the S. W. $\frac{1}{4}$, Sec. 4, T. 2 N., R. 13 W. The fact that pebbly clay occurs below the muck or peat bed, and no pebbly clay is found above in each case leads to the belief that they are post-Illinoian in age.

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[1] Fuller, Myron L., and Clapp, Frederick G., Patoka Folio, No. 105, U. S. Geol. Survey, 1904, p. 3, column 3.

The majority of the wells in the Sumner quadrangle, (by actual count about 55 per cent of those affording data) are supplied from the rock, such wells being found scattered over every part of the area. Some of these wells are entirely drilled, while others are dug until rock is reached, and holes then bored in the bottom of the well, and still others are entirely dug wells. The depth to which the wells penetrate the rock varies from about 15 feet to 60 feet or more, and the distance to the rock varies from 5 to 35 feet or occasionally more. The depth of the drilled wells varies from about 30 feet to 150 feet or more. The best water supply in this type of well is usually found in sand rock.

About 10 per cent of the wells of the Sumner quadrangle are supplied only from the drift. The distribution of these wells is very irregular, for in most cases where there are no sand or gravel beds, the wells have been dug or drilled deep enough to secure a good supply of water from the rock.

ARTESIAN WELLS.

Until recent years the term artesian was used to refer only to wells in which the water rose above the surface, and to some extent this is still the popular conception of the term. The word artesian is derived from the town of Artois, in France, where important flowing wells were first secured.[1] In late years, the term has been used in a number of senses, but in 1906 Fuller[2]

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[1] Fuller, Myron L., Significance of the term "artesian", Water-Supply Paper No. 160, U. S. Geol. Survey, 1906, p. 9.

[2] Ibid, pp. 14 and 15.

proposed the following definition: "An artesian well is a well in which the water rises under pressure when encountered," artesian pressure being defined as "the pressure exhibited by water confined in the earth's crust at a level lower than its static head."

Matson[1] summarizes the conditions necessary for the occurrence of artesian wells as follows:

"1. A porous bed or an open plane or channel to permit the entrace and passage of water.

2. An impervious cap to prevent the upward escape of the water.

3. An inclination of the water-bearing bed or passage.

4. A suitable exposure of the water-bearing beds or passages above the level of the surface at the well to permit the entrance of water.

5. An adequate rainfall to furnish the water.

6. An absence of openings which will permit the ready escape of water at a level below the well."

"It was formerly believed that an impervious bed below the water-bearing horizon was an essential condition, but such a bed is not everywhere necessary because the rocks below may be saturated with water. Under certain conditions, also, the impervious bed above the water horizon may be dispensed with, for the interlocking grains in the layer of sands above the water may offer

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[1] Matson, George Charlton, Water Resources of the Blue Grass Region, Kentucky, Water-Supply Paper No. 233, U. S. Geol. Survey 1909, p. 64.

more resistance to its upward movement than is offered by the well." This statement of the necessary conditions is slightly different from the previously generally accepted requirements as postulated by Chamberlin.[1]

In accordance with the above definition, many of the wells in the Hardinville and Sumner quadrangles may be classed as artesian wells, for in a large number of cases when a well had been dug for some distance in drift or in rock without finding water, holes were drilled in the bottom of the well until a good water-bearing layer was reached, and the water rose in the drill hole, sometimes as high as the dug part of the well. This frequently happens not only when the holes are drilled in rock, but even when the clay or cement rock of the drift is penetrated. In the latter cases the water-bearing bed is generally sand or gravel, which at some places lies at a higher altitude.

Concerning the artesian wells drilled in rock, a well driller who has put down a number of water wells in the region furnished a number of records of wells ranging in depth from 50 to 235 feet. He stated that a good supply of water was usually found in a "water rock" which he described as being a gray or white sandstone. In some cases it was reported that this sandstone was overlain by a thin bed of limestone, while in other places it was covered by shale. It is therefore not certain that this so-called water rock is the same bed in different parts of

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[1] Chamberlin, T. E., Requisite and Qualifying Conditions of Artesian wells, Fifth Ann. Rept. U. S. Geol. Survey, 1885, pp. 134-135.

the region. Where water was obtained from this rock, it usually rose about 50 feet in the well, the depth to the water-level varying from 10 to 60 feet according to the altitude of the surface. The wells in which this water rock was reported were confined to the west half of the area in both the Hardinville and Sumner quadrangles. The elevation of the top of the water stratum was found to vary from 380 to about 425 feet, wells in which the rock was found at the lower elevations being farthest west. It seems quite certain that the anticline governing the occurrence of oil along the east side of the area also affects the rocks near the surface. If this is the case, the higher elevation of the rock in the anticline, with the probable truncating of the water-bearing horizon beneath the alluvial materials of the flood-plain of the Embarass and other valleys, and the impervious limestone or shale above the sandstone, would provide the necessary conditions for artesian wells. Only one flowing well was seen. This was in test boring for coal, in the northeast corner of the S. E. $\frac{1}{4}$, Sec. 29, T. 3 N., R. 12 W. The hole was 403 feet deep and the water just barely overflowed the pipe at a height of 1 foot above the ground, but since the casing reached only to a depth of 55 feet it is impossible to say from what level the water comes. However, since 25 feet of gray sandstone, overlain by shale, was penetrated at a depth of 46 feet, it seems possible that this furnishes the water, and that it is the same water horizon that is found in other wells. The elevation of the top of this sandstone layer is about 425 feet.

It is probable that a study of some of the detailed oil well records, combined with whatever data is available elsewhere in the region, will show that artesian (non-flowing) wells may be found thruout a large part of the area. In many of the oil wells it is reported that artesian conditions are found when the wells are being drilled, the water frequently rising considerable distances in the drill holes. However, the waters encountered at the great depths are usually saline, and not fit for domestic use.

SPRINGS

A few springs are found in the Hardinville-Sumner area. In most cases they occur on the hill sides. Their occurrence is explained as follows: The rain-water sinks into the ground, until it encounters a porous sand or gravel layer in the drift, or a sandstone bed in the rock formations. It tends to follow the porous bed, rather than to sink further into the underlying impervious clay, shale or limestone. If the continuity of the water-bearing layer is broken by a hill side exposure the water will flow out at the top of the impervious bed underlying the ~~impervious~~ porous layer. Most of the springs in the area are from sand beds above clay.

QUALITY OF WATERS.

The water from most of the wells is quite palatable, but in some places it has a disagreeable taste or odor. This is especially noticeable where a well is dug thru a layer of muck containing decayed wood, or thru a coal seam. In the latter case the water has a sulphurous taste. In some places the water was reported to have a very bitter taste, and in one such well buckets left in the water are said to soon become covered with a white coating. In digging post holes at a place about 200 yards north of the Hickory Point School, in Sec. 33, T. 4 N., R. 14 W., minute white or colorless crystals of gypsum were found in the drift at a depth of about 2 to 4 feet, the deposit being fairly concentrated. A well digger living in this vicinity stated that he believed the bitter taste of some of the well waters to be due to this mineral.

The hardness of the water varies in different localities, and even in strata lying at different depths in the same locality. For instance, in a well on the flood-plain of the Embarass River, the water from a sand bed at a depth of 14 feet was soft, while the water from a gravel bed at this same place at a depth of 26 feet was said to be hard.

One or two cases were reported in the oil fields where the water had acquired a salty taste since oil wells had been drilled in the vicinity. This taste is probably due to the fact that the ground water has assimilated salt which had come from the oil well, for salt water is frequently found at great depths in the oil wells.

TYPES OF WELLS.

The type of well used depends largely on the nature of the water-bearing stratum. In loose materials, such as on the flood-plain of the Embarass River, the driven well is very common.

This is simply a perforated "pump-point" or screen attached to a sufficient length of pipe which is driven thru the loose material until a sand or gravel bed is reached. It is necessary, however, that the material of the water-bearing bed be so coarse that it will not filter in and clog the screen and pump-point. Driven wells are usually safe from a sanitary standpoint if they are driven to a sufficient depth to avoid surface water.

In areas underlain by glacial drift this clay is usually so stiff and compact that wells cannot be successfully driven. In such regions the dug well is common. In the construction of dug wells care should be taken to see that the upper part of the well is walled in such a manner that surface water cannot enter, and in addition they should have the curbing raised a few inches above the ground. Where water can be obtained from sand or gravel beds in the drift the bored well is sometimes used. This consists of a narrow hole bored with a post or well auger. This type of well, however, is not successful in places where the water is obtained only from clay, for the volume of water stored in a well of such small diameter is very small, and since the water seeps in only very slowly from the clay or drift, such wells are easily pumped dry, whereas when such beds are sunk in the more porous beds the water will run in almost as fast as it is pumped out. It is therefore advisable, when digging a well in a region not underlain by the more porous beds, to make the diameter of the well large, thereby enlarging the storage capacity. The difference in the storage capacity of a bored well and a dug well is shown in figure 7.

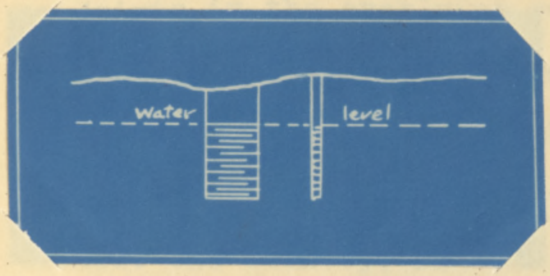

Figure 7.--Relative size and storage capacity of dug and drilled or bored wells.

In areas where a sufficient supply of water is not found in the drift, and it becomes necessary to penetrate rock in order to secure water, the wells are ~~found to be~~ of three general types; first the dug well, second, the drilled well, and third, a combination of the dug and drilled well. Where it is known that water may be found within a few feet of the rock surface the dug well is usually cheaper than the drilled well. However, in some regions it is necessary to go to considerable depths to find an abundant water supply, and in such cases it is advisable to put down a drilled well, using either hand or power drills. Unless the water is under pressure the drilled well affords only a very small storage capacity, as is the case with the bored well. (See figure 7.) However, if a charge of some explosive is "shot" at the bottom of the drill hole, it shatters the surrounding rock, and serves to make a larger reservoir.

In some parts of the area, as shown above, the water is under pressure, and rises in the drill hole when the water-bearing stratum is tapped. In such cases, if the water rises to within a few feet of the surface, it is advantageous to dig a well around the drill hole which may serve as a reservoir.

Where wells are drilled for any distance casing should be put in down to the water-bearing rock, for if this is not done, and the water rises under pressure, it may escape thru crevices or joints in the overlying rock, thus decreasing both the pressure and the supply. The fact that many drilled wells have not been properly cased is probably responsible in a large degree for the lowering of the water-level in many water-bearing strata thruout the country, and the necessity for the use of casing cannot be overlooked.

Methods of Raising Water.

The methods of raising the water vary greatly in the area. A surprisingly large number of farmers still cling to the old method of drawing water by rope and bucket. Many people use the common hand pump, there being two styles of this type; the low pitcher pump, best adapted for driven wells, and the larger hand pump for deeper wells. Only a very few windmills are used in the area. At the power houses in the oil fields, gas or gasoline engines are frequently used to raise the water, but only one or two engines were seen in use for farm wells. None of the methods of raising water by various systems of compressed air were seen in use in the Hardinville or Sumner quadrangles.

CONCLUSION.

It has been shown in the foregoing pages that the physiography of the Hardinville and Sumner quadrangles differs greatly from that of glaciated regions farther north which have been covered by ice sheets later than the Illinoian. The contrast is due largely to the fact that this area was covered only by the Illinoian glacier and that it lies near the southern limit of glaciation of that epoch, the result being that only a thin mantle of drift was deposited, leaving the main topographic features still dominated by the pre-Pleistocene rock surface. These conditions have produced a variety of occurrence of the underground waters, the wells in the area being supplied from sand and gravel beds of glacio-fluviatile, fluviatile, and aeolian origin, from drift clay, and from the underlying rock formations. The distribution of the different water-bearing strata varies greatly thruout both quadrangles, but in many parts of the region the beds are fairly uniform.

The Hardinville-Sumner area should be of interest to students of many branches of geology. For the physiographer there is a variety of interesting topographic forms. For the student of glacial geology there are a number of problems still to be solved, including a more detailed mapping of the pre-glacial topography of the Embarass River valley, the determination of the exact age of the flood-plain deposits of this and other valleys, the occurrence of the cement rock in the drift, and many other questions which have been discussed only briefly in this paper. For the stratigrapher there are numerous outcrops of Pennsylvanian rocks, some of which contain numerous fossils, and the deep oil wells in part of the area afford ample opportunity for the study and correlation of the deeper lying rocks. And finally, for the hydrologist there is still much to be done in the study of the water resources of the area. A report on the artesian waters of the region is desirable, and especially would such a report be of value to the towns of the quadrangle, for as yet none of them has a public water supply, and most of them depend on shallow water wells. If any municipal water systems are installed it will probably be necessary to penetrate the underlying rocks in order to find strata furnishing sufficient water for public use.

B I B L I O G R A P H Y .

Below are listed the more important publications which have been consulted in the preparation of this paper. They may be conveniently divided into two groups: 1) those of a general nature, and 2) those affording information concerning the more immediate region described.

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